Managing the Design Process in Construction: A Cognitive Approach

by

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CONTAINS PULLOUTS

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All mistakes, errors and omissions are solely the responsibility of the author and should not reflect on any of the many people who contributed to this work.

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Abstract

The effective management of modern complex construction projects requires a clear understanding of how the stages and players involved interrelate. From the inception of the project onwards, information is generated which is then required to be adapted and communicated through the various stages to the individuals involved so as to complete the project. Of these stages, the design has always been recognised as important but, in project management terms, not easily managed. The activities involved in designing are complex and there is a need to employ the services of an increasing number of specialists.

This research uses the framework developed in Business Process Re-engineering (BPR) to establish the existing process involved in developing and managing the design. An important element of the building, the façade, is used as an example of what happens more generally and the research is based on an in-depth case study approach of four UK construction projects. To deal with the quantity and quality of the qualitative data, the methodology of cognitive mapping is used to first create, and then analyse, the perceptions of key decision makers involved in the creation and management of the design. Using computer based analytical tools the data is filtered through a number of stages to produce summaries of the process of design.

The results of the research identify the need for the communication of the key project objectives, together with the formation of a strategy for achieving these objectives, at the outset. Selection of the right individuals, at the right time will significantly increase the development of the team approach, which is necessary to successfully develop the design. Finally, the use of formalised reviews can ensure that design progresses so as to meet the project objectives.

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Introduction

> "Architects are expected to produce working drawings and the builder is expected to carry out works in accordance with such drawings. The structural engineer relies upon the manufacturers to design the connections for the steel frame. The services engineer expects a subcontractor, appointed after the builder, to prepare all installation (i.e. working drawings). Design co-ordination before construction starts is therefore impossible and ad hoc alterations on site are inevitable....".
>
> Extract from a quote from Mr. James Nisbet, former President of the Quantity Surveyors' Division of the Royal Institution of Charter Surveyors, quoted in Sir Michael Latham's final report 'Constructing the Team'. (1994)

1.1 The context of the research

The legacy of the extraordinary boom in the UK construction market during the last half of the 1980s was a domestic construction industry which had developed a range of new systems, procedures, procurement routes and contractual relationships. The rapid decline of the market which then followed has enabled a prolonged period for reflection and consideration of how effective and beneficial these changes have been. The results of this period are spread across the whole industry and range from the large number of individuals who lost their livelihood through failed businesses, through companies that have survived and adapted to the new business environment, to the Government who has introduced new legislation and published the powerful critique of the industry, from which the above quote is drawn. In addition to those who actively participate in the industry; the clients of the industry, both state and private sector, have become a powerful voice. Through the formation of representative bodies, or indeed simply because of their proportionate increase in power when the market is slack, there is a growing realisation that the client can be a major force for change in an industry which has tended to perceive them as a relatively passive player.

It is in this context that this research lies. The realisation that there are long term structural changes taking place to the UK industry has been in a powerful force for examining how the industry operates, with many within the industry acknowledging that a change to the traditional systems and cultures present is increasingly inevitable. In the wider managerial environment there have been a number of management tools and techniques which have either been widely adopted or strongly suggested as ways and means of significantly improving key business performance metrics. These new tools, ranging from benchmarking to partnering follow on from the widespread introduction of quality assurance and Total Quality Management, which are now established as a part of the management solution to the issues of variability of service or product and business effectiveness and efficacy.

The focus of this research is at the micro level of the industry and focuses firmly on the management of construction projects as a core activity of the construction industry. Within the general area of project management there are distinct sub disciplines associated with time, cost and quality management. Similarly, the project is broken down into its various stages including developing the brief, developing the design, constructing and commissioning the facility and maintaining and altering the building during its lifetime.

1.2 The Changes in Construction Project Management

The cross fertilization of information, procedures, cultures and expectations between both industries within the same national economy, and across international boundaries has had a significant impact on the UK construction industry. From the adoption of US style forms of contract in the early 1980s, through to the introduction of Japanese management tools and techniques, the UK industry has attempted to improve its operations. Behind many of these innovative changes have been client organisations who have challenged the accepted norms and either suggested or required new approaches. If these forays are successful then the organisations learn and re-introduce the positive lessons learnt in an attempt to gain competitive advantage. In this way new forms of contracts are introduced, quality management has been widely introduced and, most recently, safety management has been introduced as an important aspect of the overall management of some of the largest and most complex projects.

The expectations of the client organisations have increased significantly in the last ten years with many traditional assumptions and procedures being challenged by client organisations who have an ever deepening understanding of the construction industry. One of the changes that this has created is that construction organisations are having to accept that they need to satisfy increasingly stringent criteria and to be seen to be proactive in the search for more effective methods of delivering a satisfactory product and service.

1.3 The Importance of Design Information

The transformation of original need into a built facility requires the involvement of a range of design experts and other skilled individuals who work on creating and developing a complete design which can be manufactured, installed and operated in accordance with the requirements and constraints imposed by the client and external influences. The development of the design can be viewed as an exercise in increasing information and transmitting this information to those who need it. With the increase in information there is a corresponding reduction in uncertainty so that by the time the project is completed the level of design information is at its maximum limit with a corresponding minimisation of uncertainty. This development is shown in figure 1.1

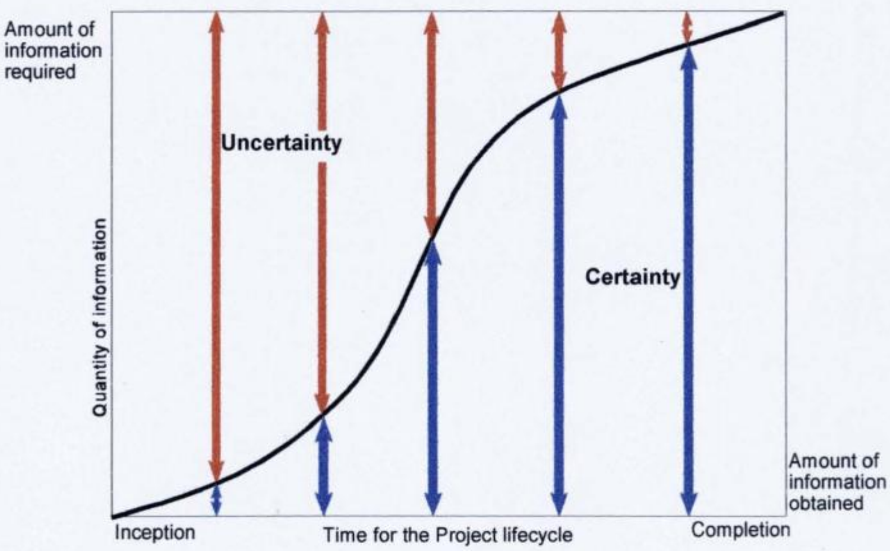


Figure 1 The level of information through a project's lifecycle

Information is the key to project management and it is the creation, manipulation and communication of this valuable resource that is examined in this research. The particular type of information considered will be design information which is the foundation on which the project is constructed.

Understanding design information is a complex problem. The research considers the question from the viewpoint that information is a manageable resource and indeed, it is necessary to manage this key resource. This establishes that the definition of information is that which is currently is used by those in the industry to create designs which are subsequently manufactured, installed, commissioned and used. The original desires and objectives of the client would be the formation of the information flow, with architects, other design specialists, an array of consultants and manufacturers, being involved in the development of the design and hence participating in the information flow.

The research therefore has a clear question which it attempts to answer. It is to understand what constitutes the existing design process on modern complex construction projects. This understanding enables its management to be better planned and organised, which is an important factor in improving the efficiency of the industry. This research will also form part of the foundation of any fundamental reengineering of the design process, something which is being discussed through forums such as the Innovative Manufacturing Initiative (IMI) and the 'new' strategy of partnering.

To achieve the objective of understanding the design, the research sought to capture data from real projects which were either still 'live', or recently completed at the time of the study. This led to a case study based research programme, where the particular issues on each project were considered in great depth. Before this stage of the research is considered, there are a number of important areas which are required to be examined first.

1.4 The format of the research

For this research to be of value, a review of the understanding of design is necessary and this is carried out in the following chapter. The development of project management, as both a discipline within general management and as applied in the construction industry, is considered in chapter three. Chapter four examines the theoretical development which has been postulated by the development of Business Process Reengineering (BPR) which has been widely adopted in many industries across the world. The move from functionally demarcated management to a process orientated management is seen as the most radical solution, but one which offers the possibility of dramatic improvement in key business performance metrics. The understanding of the theory behind this new management philosophy is necessary if it is to be applied to the highly dynamic context of a construction project.

Chapter five considers a pilot case study which examined the design management operations on the Glaxo Campus Project, one of the UK's largest and most expensive construction projects of the first half of the 1990s. This project offered the opportunity to explore the range of issues which were part of the design management for the project and which employed industry leading organisations using modern management methods.

Having built a theoretical basis on which to work the methodology for exploring this complex area is detailed in chapter six, which introduces the method associated with cognitive mapping, which is used to analyse the detailed perceptions of those key decision makers involved in creating and managing design information. Chapters seven, eight and nine record three case studies which describe and analyse, in depth, the management of the design of the façade for a large and complex R&D headquarters building, the refurbishment of a large Grade 1 listed production building and a technically innovative speculative office and retail development respectively. Chapter 10 compares the results found across the three case studies and chapter 11 draws general conclusions for the UK industry and makes recommendations for improvement.

The research will be of interest to a diverse range individuals. Firstly, there will be those who are engaged in qualitative research who will find the application of cognitive mapping to an area where there is no direct problem *per se*, novel. Secondly, researchers and consultants who are interested in the understanding of what constitutes a process, particularly in preparation for a Business Process Reengineering exercise, will find the work on the mapping of an existing process significant. Lastly, practitioners in the construction industry, whether clients, project managers or consultants, will find the way in which specific project issues appear to have factors which can be generalised across all the projects, of great interest.

Chapter Two
Literature Review
Design

2.1. Introduction

The complex way in which modern construction projects are managed in the United Kingdom can be understood more easily if the key elements are analysed. Of these elements, the importance of the design function is fundamental, and its potential influence crucial, yet it is a relatively poorly understood area. Within the range of activities which comprise a construction project the most significant distinction between key stages is that between design and construction. Two distinct groups operate during these two stages with different actors, different skills, work cultures, and motivating forces. Although dependent upon each other for a successful outcome, there is a view that design activities are cerebral and creative and are hence not accessible to the logical management dissemination which has been applied to the majority of the construction activities.

If the design stage of a construction project, or indeed any new product, is considered in basic principle, then it becomes clear that the purpose of design is to generate and communicate information. The information will tend to comprise many formats, from graphical to textual, increasingly generated on computer and transmitted electronically, and is often highly complex, requiring formal skills in order to comprehend. Treating the design stage as the key source of information enables the subsequent transformation of raw materials into a useful and valuable product.

In attempting to consider the possibilities for improving the effective information flow on dynamic construction projects, it is a fundamental requirement to understand the constituents of the information and how this information evolves. As this information is primarily linked to the design, a starting point for analysis is the understanding of design information and those that produce it.

2.2 Understanding Design

A study of the literature on design is an onerous task since there has been a fascination with the issue of design going back many hundreds, indeed thousands, of years, including the work of early Chinese cultures, the ancient Greeks, and Romans, together with the relatively more recent work of Galileo and Leonardo De Vinci. The theory behind design, however, has a much shorter history. Psychologists first became interested in the thought processes underlying creative designers during the mid 1950s. A significant contribution to this area of study was the work of Donald MacKinnon at the Institute of Personality Assessment and Research at the University of California, Berkeley (MacKinnon 1962A). MacKinnon supervised a comprehensive study of creative professionals, including architects, to try and understand the principles of creativity. His work drew upon many areas of design, from pure art to science and technology. MacKinnon's definition of creativeness therefore encompasses a wide range of influences and achieves three conditions:

> 'It involves a response of an idea that is novel or at least statistically infrequent. But novelty or originality of thought or action, while a necessary aspect of creativity, is not sufficient. If a response is to lay claim to being part of the creative process, it must to some extent be adaptive to, or of reality. It must serve to solve a problem, fit a situation, or accomplish some recognizable goal. And thirdly, true creativity involves a sustaining of original insight, an evaluation and elaboration of it, a developing to the full'.

This considered definition has to be questioned in the context of modern architectural design. Although true for a small percentage of the architectural population, there is an overwhelming proportion of architects who would consider such a definition as being of little relevance to modern design needs. Indeed during the early 1960s it became increasingly clear that building design was being dominated by the industrial 'system' build techniques which demonstrated a lack of concern for any creative detailing (Banham 1962). This was not surprising as there was a conscious movement by building design professionals to develop purely rational designs solely to achieve functional buildings which allowed pre-described activities to take place. This functional dismemberment of design into sub-assemblies has continued since this time and marked a significant development in the methodology of building design.

The study of design requires a breakdown of the global subject into more discreet sub-sets. For instance, from the above it is clear that there is a substantial difference between the design characteristics of modern architects and those of pure artists. The architectural profession is seen as being at the boundary of art, science, and technology. Increasingly there has been a separation of the architect and building design professional from the other areas of design, notably industrial design, and 'creative' design (advertising, fashion, and media formats, for example). These other areas of design have led to the development of centres of dedicated study and a separate literature (see the work of Oakley, M., Lorenz, C., The Open University Department of Design Studies).

Even within the area of architecture there is further sub-division between architecture and design. Linton (1988), for example, examines the professional design practice and considers the rôle of an architectural designer. He describes such a person as living on...

> '...a professional borderline between architecture and design; they consider the design elements of buildings although they may not be responsible for the overall structural and functional design, they can help clients by offering advice and service on the appearance and development of retail outlets'.

Early academic work on design concentrated on developing design methods which could be used. Jones, J.C.(1980) proposed a way of organising the design process so that logical analysis and creative thought would proceed in their own different ways. He suggested the use of externalised procedures so that the individual was freed to pursue resolution to problems. It was not long before criticism of this 'systematic' approach began to point out that this was unrealistic and merely attempted to treat problems without understanding them. This led to a new level of study on the structure of design problems. The emphasis of this work typified by Levin (1966) was to understand the special attributes of design problems and to seek similarities between design problems and other types of problems. Levin. for example, sought to link design and mathematics and suggested that design solutions which were based on geometrical patterns were proof of the 'ordering principle'. Alexander and Poyner (1965/6) believe that a design can be factually right or wrong <u>if</u> all the criteria are objectively written. To achieve this they attempt to substitute tendencies for needs. A design problem is, in their terms, where tendencies come into conflict. Their aim is to establish an objective body of design knowledge which can be used to solve these conflicts. Rittel and Webber (1964) stress that design will always be problematical if there exists 'wicked' problems. They list 10 properties of wicked problems which differ from 'tame' problems which are capable of being solved scientifically. The properties of wicked problems are:

1. They have no definitive formulation.
2. They have no clear 'end'.
3. Solutions are true-or-false, but are not good-or-bad.
4. There is no immediate or ultimate test for a solution
5. Each solution will be specific to a problem with no allowance for trial-and-error.
6. There is no enumerable (or exhaustively describable) set of partial solutions, nor is there a well described set of permissible operations that may be incorporated into the plan.
7. Each wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong

Simon (1969) follows this work suggesting that there is no clear grouping but rather a spectrum, ranging from 'well-structured' problems through to ill-structured problems. This approach started to be questioned during the early 1980s as the rapid development of computer data processing, with the ability to generate solutions to partially defined problems, was seen as being a panacea for these type of problems. In certain engineering applications this approach is used, for example, Rolls Royce PLC employed a substantial proportion of the UK's super computer capacity in a design exercise to calculate the optimum configuration for turbine blades for its replacement for the RB211 engine. However, this use of data processing in the field of design is still limited to analytical modelling and is used to test and observe design alternatives entered by human designers.

2.3 Moving towards a theory of design

The work in this field led to increased interest in the psychology of the design as previously covered by the work of MacKinnon and Baron. Darke (1984) looked at the formulation of a 'primary generator' which is the initial 'spark' of an idea. Akin (1984) dissected the design activity using Protocol Analysis, where designers are required to verbalise their thoughts for recording. Experiments were conducted to establish exactly what processes occurred during a simple design task. Akin's results suggested a hierarchy of design strategies. Lawson (1984) also conducted experiments using designers but chose to compare the difference in approach between professional designers and scientists when faced with identical design based problems. His conclusions were that designers seek solutions in a completely different way from scientists and therefore it was probably unlikely that scientific techniques would be applicable to design problems. The debate on how design problems are best tackled led to a further area of design which considered the philosophy of design and the fundamentals of the theory of design.

Hillier, Musgrove, and O'Sullivan (1984) consider the philosophy underlying design and how an understanding of this is necessary for ongoing design research. In order to establish a coherent philosophy for design they use analogies with the philosophies which underpin traditional science. Their argument is that designers do pre-structure their problems. The model they develop has at its core a conjecture-analysis approach rather than the scientific approach of analysis-synthesis. March (1984) differs in his approach and suggests the concept of 'abduction' as a third mode of reasoning besides deduction and induction (must be, actually is, maybe). Although seemingly different, the work of Hillier *et al* and March is similar, with the former developing a pre-structure-conjecture-analysis model compared to the latter's presupposition-conjecture-analysis-evaluation model. Broadbent (1988) looks at the theory of design and considers the differences between designing and theory building. His conclusions are that although fundamentally different, the process of designing is intellectually more complex than that of theory building. Daley (1969) examines the status of knowledge claims within design methodology. She suggests that the knowledge of design may be better understood as being 'gifted' rather than communicable verbally. Kasperson (1978) examined the differences between engineers who had a reputation for creativity and their colleagues who provided less 'inspired' solutions. He found that the creative engineers sought information from a much wider field than engineers who used only conventional sources and accordingly came up with only conventional answers. Peterson (1985) undertook a character assessment of engineers and planners but expanded his conclusions to cover a wider range of design professionals. His conclusions for outstanding engineers and planners are characterised by open mindedness, a high tolerance for ambiguity, orientation to purpose, a preference for soft or subjective information, and a facility for working with others.

By the early 1960s there had developed significant advances in the areas of systems engineering, operational research, information theory, and cybernetics, which combined with new developments in mathematics and computing. These were all available to the design theorist and were crucial factors to the development of design as a discipline in its own right. A kèy centre for this development was the Ulm school of design, the *Hochschüle für Gestaltung*. Following the Bauhaus influence of Max Bill, a series of influential designers began to heavily influence design theories and methodology. Of these, Hans Gugelot, a well respected industrial designer published his design method (1963) which includes the following stages:

1. Information Stage: one finds out all one can about the firm one is designing for, its production programme, any emphasis or shift of emphasis towards a particular class of product. One must review similar products or other firms and find out generally all one can about the field one is working in.

2. Research Stage: one must find out all one can about the *users*; too often, decisions on user 'needs' are made by a committee which, by reason of status alone, is incapable of knowing what users really want. One tries to assess the *context* in which the product will be used; at the same time, one looks into function, possible production methods - especially new processes and developments.

3. Design Phase: here the designer can be creative; one looks for new *format* possibilities. Where no formal idea is forthcoming, then one must fall back on variations of existing forms. During this phase, one must bear in mind the needs of other people who will be involved in making the product.

4. Decision Stage: one seeks a favourable decision from sales and production managements. If the design is radically new, then there may be great difficulties in 'selling' it to them.

An adventurous sales manager might be persuaded to take a calculated risk, but production can *only* be persuaded by sound, technical argument.

5. Calculation: this is a matter of adjusting the design to specific production standards and, if it is done intensively, then the design itself can be utterly spoiled. Production departments often fail to realise that alterations which seem slight to them often have grave formal consequences. There must be continuous two-way communication.

6. Model-making: one builds a prototype, a working model which is a great help in production planning, and helps demonstrate the limits of any technical risk involved.

At about the same time Morris Asimow produced his *Introduction to Design* (1962) which formed the first part of a series of books edited by James Reswick under the general title of *The Fundamentals of Engineering Design*. In his book, Asimow considers design as information processses. Design, he says, consists of

> 'The gathering, handling and creative organizing of information relevant to the problem situation; it prescribes the derivation of decisions which are optimised, communicated and tested or otherwise evaluated; it has an iterative character, for often, in the doing, new information becomes available or new insights are gained which require the repetition of earlier operations'.

Asimow's methods follow from systems engineering, and he describes two scales of operation, one of which loops within the other. This method, his strategy, he refers to as the design *morphology* and it comprises the following stages:

1. Feasibility Study-Phase I
2. Preliminary design-Phase II
3. Detailed design
4. Planning the production process
5. Planning for distribution
6. Planning for consumption
7. Planning for retirement of the product

The detailed design phase is further sub-divided:

1. Preparation for design
2. Overall design of subsystems
3. Overall design of components
4. Detailed design of parts

5. Preparation of assembly drawings
6. Experimental construction
7. Product test programme
8. Analysis and prediction
9. Redesign

Finally, Asimow outlines a general process for solving problems which he calls the design *process* and which also has its stages:

1. Analysis
2. Synthesis
3. Evaluation and decision - which is extended into:
4. Optimization
5. Revision
6. Implementation

The first *Conference on Design Methods,* held in 1962, concluded with Page who summed up the three phase sequence at the centre of design as:

(a) analysis
(b) synthesis
(c) evaluation

This model for design was, and has subsequently been, widely used and upheld by design methodologists and theorists in all disciplines.

Jones (1980) considers the various ways in which design is undertaken in a wide context. He makes the important distinction between the procedure, which he associates with the paperwork, and the process, which is the intellectual analysis. His thoughts of the many methods of designing are ultimately to provide a similar result. He writes:

> 'The purpose of any method of designing, orderly or muddled, is to get one's mind to be familiar with the unknown possibilities and limitations of "the new" before making irrevocable decisions.'

A very interesting point is made by Jones when he quotes other noted contributors on the design debate on their definitions of what is designing:

> 'Finding the right physical components of a physical structure'. (Alexander, 1963)
>
> 'A goal directed problem solving activity'. (Archer, 196)
>
> 'Simulating what we want to make (or do) before we make (or do) it as many times as may be necessary to feel confident in the final result'. (Booker, 1964)

'The conditioning factor for those parts of the product which come into contact with people'. (Farr, 1966)

'Engineering design is the use of scientific principles and technical information in the definition of a mechanical structure, machine, or system to perform prescribed functions with the maximum economy and efficiency'. (Fielden, 1963)

'Relating product with situation to give satisfaction'. (Gregory, 1966)

'The performance of a very complicated act of faith'. (Jones, 1966)

'The optimum solution to the sum of the true needs of a particular set of circumstances'. (Matchett, 1968)

'The imaginative jump from present facts to future possibilities'. (Page, 1966)

'A creative activity - it involves bringing into being something new and useful that has not existed previously'. (Renswick, 1965)

Jones sums up these diverse definitions with the simple yet elegant

'To initiate change in man made things.'

The analysis of design methods provides a useful insight into the complexity and degree of change that has taken place involving design issues. An interesting issue that Jones points out is that designers work in the future and backtrack to the present. This establishment of end achievements before the detail of the process is formalised distinguishes design problems from other categories of problems and requires separate analysis.

Having considered the definition of what is design and, by so doing, introduced a number of important concepts, there is a progression to develop a coherent and reasoned series of design methods. Initially these recommendations are not discipline specific but draw attention to the fundamental issues involved. Jones' choice for the criteria for design project control are:

1. Identification and review of critical decisions - where important decisions should be taken early and tentatively if it is likely that later information will prove that those decisions are wrong.

2. Relating the costs of research - the design should consider the penalties for taking the wrong decisions.

3. Matching design activities to the persons who are expected to carry them out - this is of key importance to the certain sectors, particularly construction where the variation in specific skill types and experience is so great that there will be a range of outcomes dependent on who is chosen.

4. Identifying usable sources of information - a good design will have taken into account factors which are pertinent to it. However, there will be a need to limit the depth and breadth of information sought as time and budgetary constraints will have to balanced.

5. Exploring the interdependencies of product and environment - here the product can be seen as a metaphor for all design projects tangible or otherwise. A good design consciously considers the impact that the product has on the environment and vice versa.

The process of design is seen by Jones as comprising three stages which he terms Divergence, Transformation, and Convergence. These elements are shown in figure 2.1.

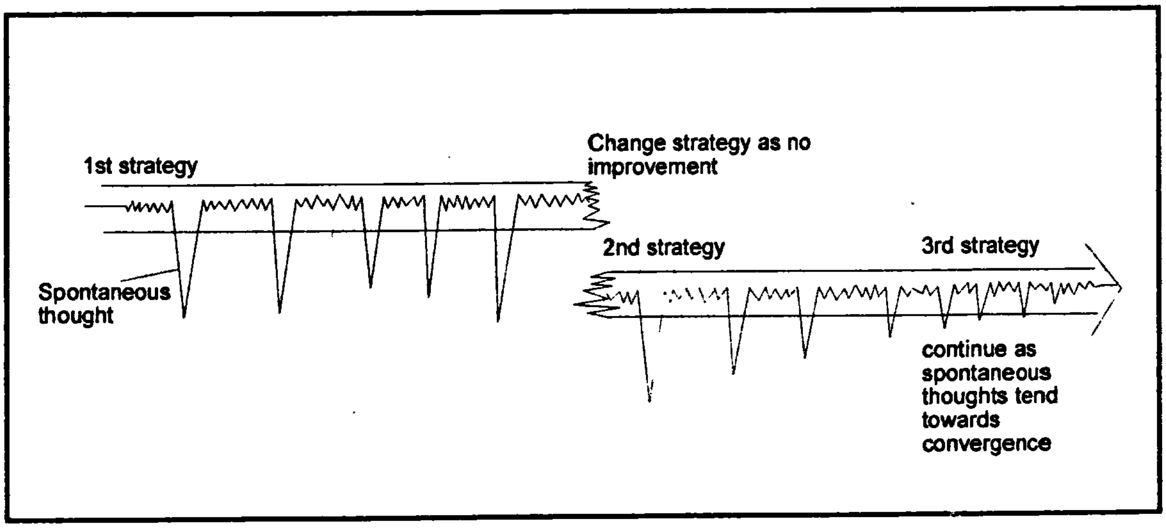


Figure 2.1 Track of designer's attention, Jones (1980)

Figure 2.1 suggests that a designer or design group may well pursue the wrong solution initially. This continues until some critical point is reached at which a lack of resolution leads to a fundamental rethink. Such actions imply the use of strategies. Jones defines a design strategy as...'Simply a list of the methods that one intends to use'.

Such a simple statement belies the complexity of design strategies, which can range from highly pre-planned to completely unplanned. Pre-planned strategies can be either rigid or searching and may be linear or cyclic, involving feedback loops. Branching strategies which include parallel strategies are where two or more design alternatives are progressed concurrently. These alternatives may rival each other in totality, or a particular design route may generate alternative partial solutions which need consideration. Adaptive strategies are planned only at the initial stages and follow the results as they occur, selecting only those most likely to succeed. An incremental strategy is a development of the adaptive strategy and is a traditional basis for craft design. In contrast, completely unplanned strategies or random searches, as Jones defines them, involve brainstorming or similar techniques which explore the full boundary of feasible solutions without pre-judgement.

Jones draws upon the various elements of design analysis to form a prescriptive matrix for assisting in the choice of design methods to be used on design projects. The axes of the matrix comprise design inputs, and design outputs. Jones assumes that the suitability of a method can be judged by comparing its inputs with what the designers already know, and its outputs with what they want to find out. Inputs, shown down the first column, are the kinds of information that must be available before a particular method can be used. Outputs, shown across the first row, are the kind of information that a method can be expected to produce. The two scales, input and output, are identical and are placed in order of decreasing generality and increasing certainty. The matrix is reproduced in figure 2.2.

Design problems that start with high uncertainty and a lack of information begin at the top left hand corner. Methods suitable for these uncertain stages appear in this area. As the design develops so it will move through the matrix to the bottom right hand corner. Those methods near the diagonal line are those recommended by Jones as being the most effective method for each stage. Should progression be at variance with that prescribed by the diagonal, then Jones includes design 'strategies' which should allow designers to bypass several stages. Some items are repeated in order to demonstrate that they can be used for backtracking purposes.

Jones' instructions on the method for using the matrix are as follows:

1. Find, on the input scale, the categories of information that have so far become available. The rows next to these categories contain methods that are relevant to the problem.

Outputs→ Inputs ↓ ↓	2 Design Situation Explored	3 Problem Structure Perceived or Transformed	4 Boundaries Located, Sub-solutions Described and Conflicts Identified	5 Sub-solutions Combined into Alternative Designs	6 Alternative des Evaluated and Design Selectec
1 Brief Issued	Stating Objectives Literature Searching Visual Inconsistency Interviewing Users Brainstorming	Literature Searching Visual Inconsistency Search Interviewing Users Brainstorming Synetics	Visual Inconsistency Search Brainstorming Morphological Charts	Visual Inconsistency Search Brainstorming Synetics	Strategy Switching Matchett s FDM
2 Design Situation Explored		Stating Objectives Data Reduction Interaction Matrix Interaction Net Classification Specification Writing		System Transformation Functional Innovation Alexander s method	
3 Problem Structure Perceived or Transformed	Literature Searching Questionnaires Investigating user Behaviour Systemic Testing Selecting Measurement Scales Data Logging		Boundary searching Systemic Searching Brainstorming Morphological Chats Selecting criteria Ranking and weighting Specification Writing	Brainstorming Synetics Systems Transformation Boundary Shifting	Systematic Search Value Analysis Systems Engineering Man-machine System Designing Boundary Searching Page's Strategy CASA
4 Boundaries Located, Sub-solutions Described and Conflicts Identified		Synetics Removing Mental Blocks AIDA System Transformation Boundary Shifting Functional Innovation Alexander's Method		Brainstorming Synetics Removing Mental Blocks AIDA	AIDA
5 Sub-solutions Combined into Alternative Designs					Value Analysis Questionnaires Investigating User behaviour Systemic Testing Selecting measurement Scales Data Logging and Reduction Check ists
6 Alternative Designs Evaluated and Final Design Selected					

Figure 2.2 Matrix for design problem tools, Jones 1980

2. Select, from the output scale, the kinds of information that are required next. Methods of generating this information appear in the columns below these categories.

3. Select, from the cells where the selected rows and columns cross, methods of generating the required outputs from the available inputs.

Jones acknowledges that in practice there may be problems implementing his categorisation of methods but the general principles of the matrix follow the divergence, transformation, convergence logic.

2.4 Clients and Users: The External Agents

A clearly important area of design and the processes, methods, and philosophies which have been attached to it have all had to deal with the larger context in which design is placed. All design serves a purpose. Whether that is practical, cerebral, tangible, or otherwise, there is a basic desire to fulfil a desire or need. In modern design this need is often provided by a third party. Indeed external agents to the design process provide the key element to the design problem. These agents can be considered under two broad headings: clients, and users. While these may be encapsulated in one person for some design projects, there is a spectrum where at the other extreme, both the client and user comprise many heterogeneous groups all with different agendas. It is with specific reference to these two distinct groups that attention now turns.

Although mentioned in many texts, the client's contribution to the design process has received little consideration in relation to the more abstract features of design. Yet much of the insight for the design solution will come from the client. Although it is acknowledged that many clients will be motivated by financial, time, or functional factors, there is still a need for the designer(s) to endeavour to fully understand what the client wants. Where the client is unsure, the designer has the responsibility to educate and guide, so that the client is able to make informed decisions when required.

Since much design work is commissioned, the development of the client's initial idea into the client's brief - a document summarising the design project's ultimate goal, is critical. Barrett (1993) reviews the importance of this document for construction clients and demonstrates the importance of the document as a communication tool. To aid this study Barrett employs the Johari Window Concept (Luft 1970) which can highlight the possible problem areas. This concept is shown in figure 2.3.

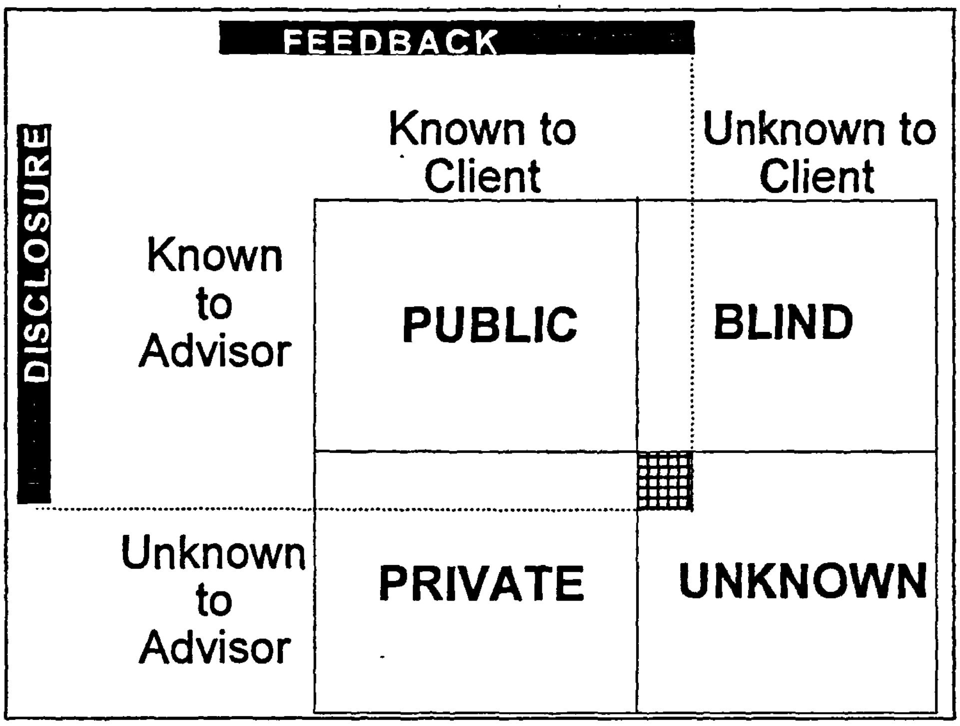


Figure 2.3 The Johari window concept

Figure 2.3 shows four main situations which may occur. The 'public' area represents the client communicating without difficulty his/her requirements to the professional designer(s). The 'blind' area is the area where information is only discovered by the designer through two way discussion with the client. This 'blind' area is resolved through what can be seen as 'feedback'. The 'private' area relates to information that the client does not disclose, whether purposefully or not. The 'unknown' area is that which neither party is aware of and can be discovered only through the use of feedback and disclosure. This twin process may still reveal only part of the 'unknown' information as shown in the diagram. The model suggests that through the life of the project the level of information will become complete, given an open and honest client. However, it is often found that much useful information becomes available only after the project is completed when the product is in use. This is especially true for buildings, where extensive testing of prototypes is not feasible. A well documented example is the Sydney Opera House where the design of the roof covering was intended to have a design life of over 300 years, yet during occupancy it was found that leaks occurred necessitating the resealing of the roof every 15 years.

As the communication process is so vital between clients and designers it warrants further investigation. Gameson (1991) has carried out a detailed investigation of the communication process through the use of recorded conversations between clients and designers at the early stages of brief preparation for construction projects. A significant finding of the analysis of these conversations was that the level of inputs from the various parties varied considerably from case to case, depending upon the client's previous experience. For example, a client with previous experience restricted the architect's input to 36% of the time, while the client spoke for 64% of the time. In contrast, Gameson reports on a case where the client had no previous construction experience. Making the necessary adjustments to allow for the heterogeneity of construction, the comparable percentages were 76% and 24%. This clearly demonstrates the diversity of information flow with the associated variance in brief.

Barrett advocates a contingency approach to briefing where the objective is to identify the appropriate approach to the briefing process given the particular circumstances present. An important criterion is the issue of leadership. All clients want the professional design advisors to provide additional services to those that they can draw upon 'in-house'. However, the form of the additional service will depend upon the client's previous experience and attitude. Barrett identifies four areas under which clients can be categorised. These are shown in figure 2.4.The professional designer is generally leading, providing varying degrees of knowledge and support to the client depending on the client's particular needs. However, in the case of a very knowledgable, confident client the roles may be reversed with the client taking the lead (influencing). Varying degrees of knowledge and support lead to the categorisations as shown in figure 2.4.

		Support Needed	
		A Lot	Very Little
Knowledge Needed	A Lot	"Help me through it"	"Give me the extra space"
	Very Little	"Do it so I can check it"	"Get on with it"

Figure 2.4 Classification of client type, Barrett (1993)

Powell (1991) considers the briefing process as a teamwork issue. He argues that clients should:

> 'Understand their own needs first and then... secure a design/build team who will reflect their own view of the world'.

He further argues that the client should bring together a team of complementary skills to 'release latent synergy'. Powell's view of modern construction requirements are that:

> 'The skills required to produce truly user responsible buildings can no longer exist in any one designer/builder'.

Garrett (1981) distinguishes between the client and the 'problem-owner' who maybe the user or other non-client party. This distinction leads to three consulting styles.

> **Expertise consulting** is where the consultant works with a client who is the main problem owner as well. This is the traditional relationship.

> **Process consulting** is where the consultant works predominantly with the problem owner in an attempt to fully understand the design problem. This communication, if it excludes the client, can unsettle the client.

The contingency approach where communication is held between the consultant and problem owners and the client.

Using the contingency approach, the consultant's role is to ensure that tactful negotiations are held between the two other parties in order to draw out the main issues. Garrett assumes that the contingency approach will be successful because:

> 'Most of the experiences needed to solve a client's problems are already in the organisation'.

By increasing the roles and responsibilities of the consultant designer, there is a tendency to move into other specialisation. The increasing involvement of facility managers who handle long term planning and life cycle maintenance, together with professional project mangers who fully understand the client's concerns during construction, will lead to closing of the professional differences between the instigators of construction projects and design professionals.

As the analysis of design considers actual situations there is a dramatic increase in the complexity of the problem. Rouse and Boff (1987) have observed:

> 'If an outside observer were to characterise designers' behaviours, particularly for complex domains such as aircraft design, it is quite likely that such an observer would conclude that chaos is the most appropriate characterisation of the design teams at work....Of course, the apparent chaos is, for the most part, due to the inability of the outside observer to know exactly what is happening'.

In attempting to understand these complex situations Bucciarelli (1988) considers how designers formulate what he refers to as 'object worlds':

> 'The attributes of the object and their interrelations constitute the object, but different constellations or sub-sets of attributes (constellations is a good word, for the attributes within a sub-set are in fixed relation) are of interest to different persons in design. These constellations are situated within theories, or models of behaviour of the object. So differently schooled participants will see the object of design differently according to their special interests. Each will work out the design task according to their design task, relying on different kinds of models, theories, tools, constraints. Each will work within a different 'object world': a world of technical specialisation, with its own dialect, system of symbols, metaphors and models, instruments and craft sensitivities'.

The important point made by Bucciarelli is that where designers of different specialisations have to combine skills in order to bring a design project to fruition, a compilation of 'object worlds' is required. Cuff (1981) has concluded from her study of architects, that the work of design displays many of the characteristics of what sociologists recognise as 'negotiated order'. The abstractly conceived objectives, methods, requirements, schedules, roles, and responsibilities of a project have to be implemented in circumstances which simply cannot be foreseen and detailed in the setting up of the project. Hence in many complex design projects the parties involved spend much time negotiating amongst themselves what the actual problems are and they will each resolve them. In such negotiation many problems are not resolved but are managed through what is essentially a process of collaboration, bargaining, and compromise. In such negotiations the user has been found to be a 'scenic feature', a term first used by Lynch (1979, unpublished) to describe what the users want, what they might do, what they would be willing to accept were treated as significant and sometimes even decisive. Sharrock and Anderton (1994) carried out case studies and found that designers drew upon data from users in a discursive way and not empirically. They found that users were referred to as part of a wider problem in which they played a part, but were not the only consideration.

Pugh (1991), writing from an engineering design perspective, sets out a process for design which includes the important *Product Design Specification* (PDS) which provides the link between the brief, or statement of clients need, and the actual design work. Although the PDS provides a rigorous approach to the necessary information gathering exercise as shown in figure 2.5, on the following page, there is only passing reference to the brief itself. In many cases the lack of a suitable brief will jeopardise all subsequent work.

Green (1996) argues that the individual client is a complex entity, requiring a more thorough examination by construction professionals. Moreover, the particular circumstances of a construction project result in a number of perceptions present, from those involved, of the organisation which forms the client. Green summarises this:

> 'clients cannot be understood simply by classifying them in accordance with a predetermined set of characteristics. It must also be recognized that there can never be any single "objective" interpretation of any organizational situation'.

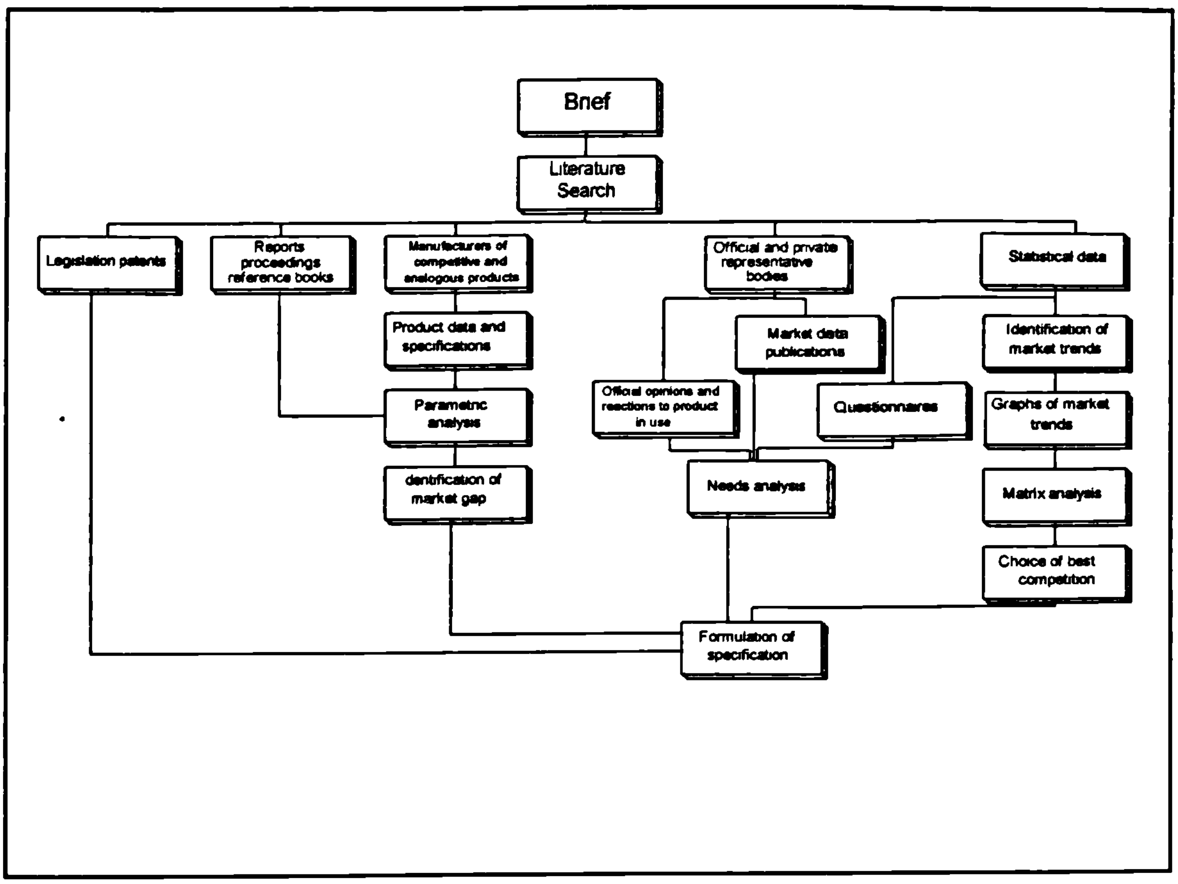


Figure 2.5 A process for design, (Pugh, 1991)

2.5 Collaborative Design

The area of collaborative design, and the factors which affect it is still a relatively new area for research. Peng (1994) considers collaborative design as the modelling of complex objects, and contrasts this with other frameworks, notably design as a game (Lawson, 1980), and reflection-in-action (Schön, 1991). Peng also notes that collaborative design is of interest to scientists working in the field of computer supported cooperative work (CSCW). An interesting development of this new research is the attempt by CSCW designers to provide *tele-presence* or *tele-data*, facilitating direct or indirect communications among members of a design team. But Peng also points out that some problematic situations remain unexplored. Little is known, for example, about the nature of cooperation where participants of different technical specialisations communicate and coordinate with each other to achieve, or to cope with, as Peng terms it, *design unity*. Peng then examines historically documented architectural design projects which used various forms of modelling, ranging from complex physical models to drawings, which assisted in design development

If the field of analysis is restricted to the built environment and the design processes utilised, there is little research which attempts to model the complex procedures employed. Atkin (1993) examines the tendency for the stereotyping of design options in various types of building. He emphasises the frame-of-reference which designers use. This work draws upon the work of Mackinder and Marvin (1982) and Harper (1978). These writers suggest that a familiar idea is often the seed from which the image of the proposed building germinates, cultivated by experiences to reinforce the idea. The important consequence of this approach is that designers do not consider all possible design solutions. Only a few designers actually consider the generate, synthesise, evaluate model which has been suggested as being the way design is progressed. Atkin also notes that this is a way of generating an architectural style and perpetuating poor design. By restricting the choice set many designs will be sub-optimal. Atkin's empirical research covered 40 building projects. He found that of the possible options available for various elements of the building (type of frame, ceiling type, for example) there was significantly less variety found. He also discovered clusters of remarkably similar design options for certain types of building, suggesting a mainstream 'blinkering' of designers who follow current trends.

To manage the reality of modern construction design, there are few tools available for companies to use. A group from Loughborough University (Austin, Baldwin & Newton, 1994) have attempted to provide a practical way for preplanning the design activities involved. A key consideration in this work was the tacit recognition that the parts of the design process involve iteration with the presence of iterative and feedback loops. Established methods such as critical path method - CPM, or the project evaluation and review technique - PERT (see chapter 3) cannot cater with this type of problem. Austin *et al* developed a matrix based model using Steward's design structure matrix, originally formulated to assist software engineers. The preliminary results of this work were ways of recognising design activities which were not capable of being fully resolved at the time because of reliance on downstream information. Such recognition itself allows contingencies to be put in place for either estimating the outstanding information or making the resultant design conditional on subsequent information. To develop this model, certain assumptions were made, most notably the research focused on the 'hard' design information activities such as the production of detailed sub assembly designs or calculations. In choosing to address the overall design activity by disaggregating it into a hierarchy of increasingly detailed design tasks, the research concentrates on the latter stages of design. Indeed, as noted by the researchers:

> 'It was deemed too time-consuming and confusing to try and model informal or formal oral communication'.

Although this exclusion can be justified for the purposes of developing a detailed modelling tool for design activity order, there is a need to understand the issues which set the context for the project being considered. Indeed it is a reflection of the vagaries of such issues as the variation in perceptions of the client, and those of the designer, as noted by Green (1996) which makes it important to have this knowledge understood and communicated before such a model, as proposed by Austin *et al*, can become a powerful management tool.

2.6 Technology in Design

A thorough review of how information technology has affected design would be a considerable task, necessitating the introduction of many new concepts and involving the areas of computer systems design, programming, and other technical specialities. It is the intention to therefore consider how technology in the guise of computers will assist designers in the future and develop into more than complex artificial drawing boards.

While Computer Aided Design (CAD) has been extensively used for nearly two decades, there has been growing interest in the use of expert design systems and real time shared computing, capable of multi-user manipulation. Recent advances in virtual reality computer modelling have also been seen as having a major impact on the progression and testing of designs.

The use of expert systems, or Knowledge Based Systems (KBS), involves the writing of complex programmes which attempt to mimic the behaviour of human experts. Although this area is technically complicated, fundamentally there lies at the heart of the computer program a series of instructions which are modelled on the real behaviour of experts. The greatest area of research has been carried out in the military, aerospace and space exploration, geology, and medical fields. In medicine, for example, computers are being used for diagnostics, for both General Practitioners and surgeons. These applications analyse a series of symptoms and associated data and then suggest causes and recommend treatments. In aerospace applications, computer navigation systems are now capable of correcting for unexpected weather conditions and, by using satellite navigation references, alter course to provide the most comfortable flight for passenger aircraft.

The use of KBS for design requires a great deal of expertise and as Pugh (1989) notes there has to be a complete understanding of the design process:

> 'In my view major steps forward in the area of KBS and design will only be made when multi-disciplinary teams are put onto the problem - with a thorough understanding of the design activity - since it is a design problem; after all, this is what we do nowadays for successful product design'.

This is where the major obstacle occurs. As there is still much to be understood about how designers *practically* go about their business, it remains an active area of research. Limited applications of KBS are being introduced into manufacturing, particularly automobile development. Pugh stresses that a distinction be considered between *generative* and *diagnostic* applications of KBS and concludes that KBS will initially develop along diagnostic routes rather than generative.

Dankel (1986) considered the practical problems of collating the information necessary to make expert systems work. He notes

> 'While it is highly desirable to employ several experts in the construction of a knowledge base, it proved to be a very difficult task - subtle incompatibilities can occur that neither the knowledge editor nor the experts will catch'.

Kirby and Bridgestock (1993) record the development of a KBS system for ensuring that all design review procedures have been followed. The application was developed by the US army for its multi-million dollar construction programme. The goal was to reduce the number of unnecessary and expensive design changes which were continually noted. The complex system uses a KBS together with hyper-text, which are nested, textual clusters. The result is a system which prompts those involved with the design project to ensure that all the correct stages *for that particular type of project* have been completed.

Recuero and Prokopious (1993) explain that computer applications in construction mirror the fragmentation of the industry. They break the building design process down into 10 stages:

1. Building specification
2. Landscape architecture
3. Urban/environmental design
4. Architectural design
5. Civil engineering
6. Energy engineering
7. Facility engineering
8. Sound engineering
9. Interior space design
10. Material selection bills of quantities

Such a sequential nature poses problems for the development of a comprehensive computer system. The consequence is that partial computer applications have been developed that do not record the knowledge gained which stops the development of sensitivity analysis (the 'what if' scenario). The current use of specialist computer programs ranging from spreadsheets to CAD has meant that research is investigating the use of common data base file formats which would allow access to a variety of users. This research is proving to be complex as the diversity of applications and user requirements means that the data has to be encoded so that it can be manipulated to meet a number of demands.

2.7 Appreciating the Problem of Design

In construction clients instigate a complex process which culminates with the delivery of a new building. In this respect, the construction industry does mirror many other industries, where clients, be they internal or external, corporate or individuals, begin a process which they ultimately judge as successful or otherwise. This judging of success is far easier for simple products than for complex processes. Where tangible criteria, such as colour, shape, function are easily measured there is a relatively easy task of comparing the final product against some pre-conceived idea. Where the final result is a service, the judgement is more difficult. To explore this area Zeithaml *et al* (1990) developed a model which considered the key difference between the *expectations* and *perceptions* of service clients. For this initial research the services considered were the provision of restaurant meals and the consultation between patients and Doctors. From this initial work the generic Gap Analysis model was developed which is shown in figure 2.6.

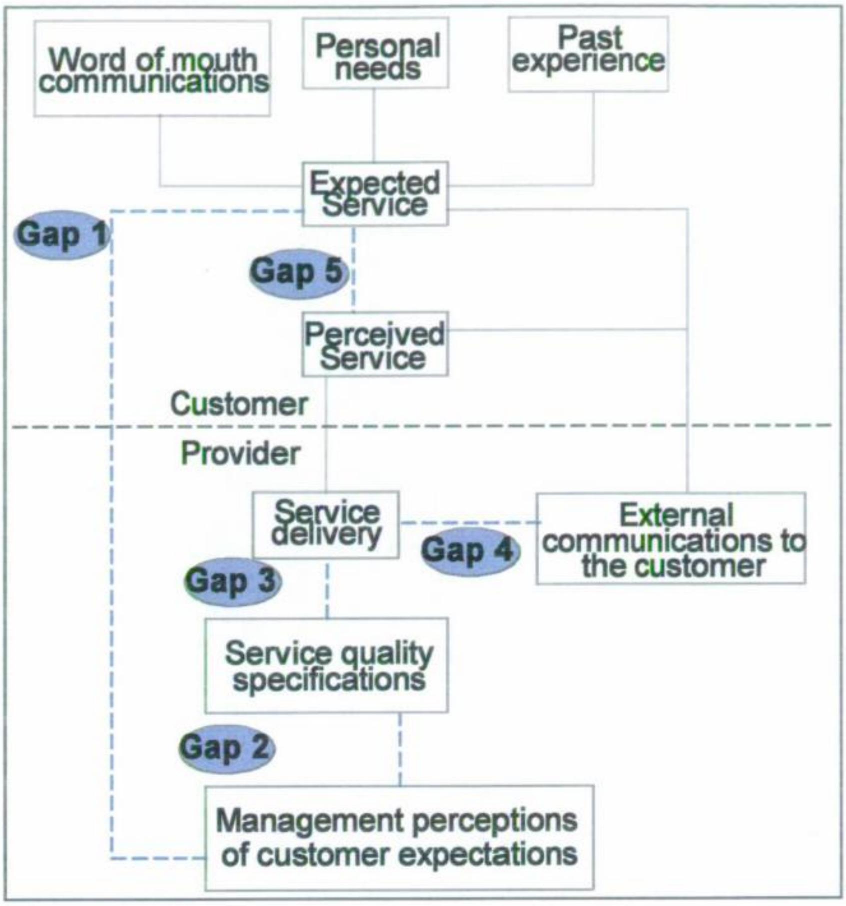


Figure 2.6 Generic service industry Gap Analysis

This intriguing model establishes a number of stages which ultimately result in the delivery of a service which the client judges. Starting with the initial understanding of the client's requirements, the service provider interprets these desires and then passes through a number of stages before finally delivering the service. The degree to which the client is able to view these 'internal' service provider processes, termed the line of visibility, influences both perceptions and expectations which the client has. Where the line of visibility is high, obscuring the process, there is a likelihood that the client will be surprised with the result. Where there are gaps present in this internal process, ranging from the briefing gap to the conformance gap, then the resultant service is likely to be less than satisfactory.

This initial work has been translated for the construction industry by Winch, Usmani, & Edkins (forthcoming) to apply to a construction project. The model provides an extremely useful way of viewing the project, and enables the problem areas to be classified into one or more of four distinct areas, which ultimately produce the *project performance gap*. This applied model can be seen in figure 2.7.

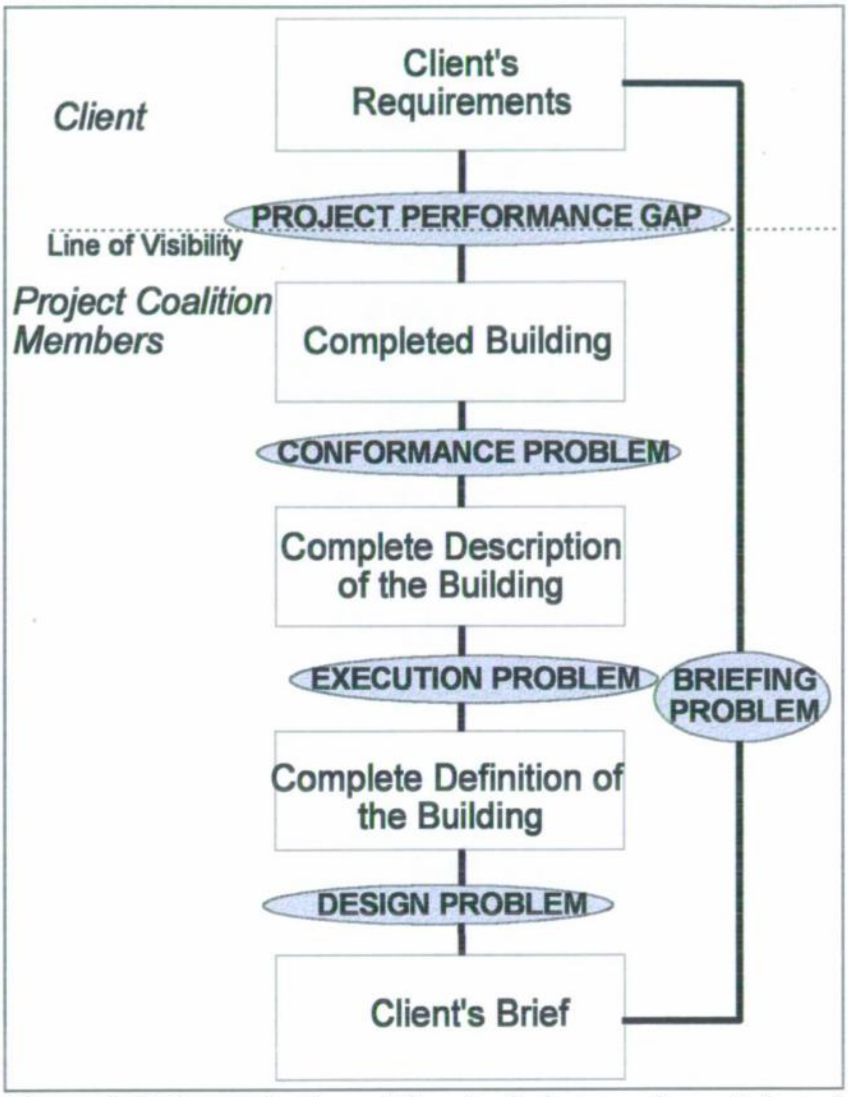


Figure 2.7 The application of Gap Analysis to projects, (adapted from Winch, Usmani & Edkins, forthcoming)

The first two 'gaps' featured in figure 2.7, namely the briefing and design gaps, can be understood from the earlier discussion. The briefing gap occurs where the designer fails to appreciate what the clients objectives and desires are. If this stage is completed successfully, then there is still the very distinct possibility that the designer may not be able transform these original ideas into a cohesive design. These stages are therefore firmly set within the context of the design problem. The remaining stages of execution and conformance involve the participation of a number of other professionals, drawn from areas of technical expertise and management. These areas will be considered in greater detail in the following chapters.

2.8 Conclusion

Having looked at the area of design, from fundamental theories to current computer applications, it has become evident that whilst a great deal has been done in an attempt to understand design, there remains a great deal which has not been studied. Of particular interest is an analysis of the complex design stage which is part of the larger project to construct elements of the built environment. This situation is increasingly common, with new building services, climate control, and environmental impact making construction projects more complex. With this complexity comes an increase in cost which, although subject to current dampening by the construction down turn, will lead to significant price rises when demand once again returns. Construction clients are increasingly aware of the problems which the industry creates and are seeking to encourage ways to improve the *total* management of a project. The increasing recognition of the complexity of the project environment is evident. From the idiosyncratic nature of the client, through the iterative nature of the design activity and involvement of an increasing number of parties, to the need to recognize the importance of expectations and perceptions of all those involved as a significant factor for success, there are many factors which need to be managed.

The next chapter will review the current approach as prescribed by the project management literature. Particular emphasis will be given to the role of the design and design professionals, together with the other players involved in a project, notably the client and users.

Chapter Three
Project Management

3.1 Introduction

As there has developed a separation of the management between process based operations and project operations, so there has developed an academic base on which these two areas of management are set. In project management (pm) this base has been overwhelmingly dominated by the work on the tools of pm which are centred on scheduling and planning aspects.

The most significant developments to pm began during the second world war and have continued during the last five decades. The military operations carried out during the war, especially the D-Day landings, demonstrated the complex logistical and planning operations that are always present on projects. The Manhattan project, which developed the atomic bomb dropped on Japan at the end of the war, was a project demonstrating the achievements which can be made by focusing attention in a highly concentrated form. After the war the advances made in pushing the technological boundaries further and further were often correlated with the use of specialised project management skills and techniques. Although it is easy to demonstrate the impressive results of such projects for example, Apollo, Concorde, fibre optic communications and many military developments capable of awesome destruction, there have been many failures and a continuing reluctance to accept project management as providing a successful approach to the complex issues involved.

This chapter will consider the impact of project management as a specific set of skills and techniques to the problems which are found on projects. As there is a wide variety of project types which have led to the development of an equally complex number of pm tools the intention is to consider the issues found on construction projects. This will therefore tend to neglect some of the issues found on significantly different forms of project, most notably R&D projects, computing, IT, software, and military projects. This lack of detailed consideration for these areas only impacts slightly on the main issues involved in generic project management issues and avoids the requirement to address specialist and complex problems which occur in these areas.

3.2 The beginnings of modern project management

The first writing on the subject of project management was by Gulick in a book edited by Urwick in 1937. In this article Gullick suggests the use of dedicated personnel which are given tasks to perform relating to several functional areas. This suggestion of a matrix form of organisation, which was the first in academic writing, followed the pioneering work of Exxon (then Standard Oil) and other emerging oil and associated processing companies who were increasingly using *Project Engineers* as a functional element of their management staff.

During the Second World War there were many examples of projects which were either campaigns, tactical plans, or military hardware developments. Individual projects to capture strategically important areas of land required dedicated military management with support of many experts using large quantities of diverse information. The race to equip fighting forces with ever more effective military hardware and weapons led to numerous projects which broke new ground. Yet of all of the citable examples, the Manhattan Project in the US to develop and harness nuclear fission and create the atomic bomb, has been used as a classic project in project management terms. the project, headed by J. Robert Oppenheimer and including many notable scientists and engineers including a young Richard Fienman, was charged with the task of releasing the power of nuclear fission in the form of bomb capable of being dropped from a bomber, before Nazi Germany. The key factors of the project in management terms were the speed of completion and the technical uncertainties. The motivation for the project came from overt threat that the opposition would succeed first with devastating effects. As the project received top level political and resource support the main objectives became the management and administration of the wide ranging elements. The dropping of the bombs on Hiroshima and Nagasaki in Japan in 1945, the first bomb being dropped untested, led to the Japanese surrender negotiations four days later.

General L. Groves (1983) who was responsible for the Manhattan Project gave five factors as being responsible for the project's success

> 'First we had a clearly defined, unmistakable, specific objective "to bring the war to a successful end more quickly than otherwise would be the case and thus save American lives". Second, each part of the project had a specific task. These tasks were carefully allocated and supervised so that the sum of their parts would result in the accomplishment of our overall mission...Third, there was positive, clear cut,

> unquestioned direction of the project at all levels. Authority was invariably delegated with responsibility, and this delegation was absolute and without reservation.... Fourth, the project made maximum use of already existing agencies, facilities and services... consequently, our people were able to devote themselves exclusively to the task at hand, and had no reason to engage in independent empire building. Fifth, and finally, we had the full backing of our government with the nearly infinite (availability of resources)'. (adapted from Morris, P. (1994) p.16

Although the financial cost of project was far higher than estimated and it overran its predicted schedule, the Manhattan project did achieve its objectives and was classed a success by the government. This last point will be considered in greater detail later.

During the 1950s the tools and systems, which have subsequently been used with great effect were developed primarily by the United States Air Force (USAF). Of particular importance were the development of Inter-Continental Ballistic Missiles (ICBM) as a response to the USSR's nuclear threat. Beginning with the Atlas missile, the US government wished to have ICBM capability as quickly as possible. Reviews were carried out by the Air Research Development Command (ARDC) which recommended a separate management committee be established. This recommendation was implemented as a technical support group employing the services of an outside company for system support. The use of such a service had proven successful during jet aircraft development where a system was specified and components designed which conformed to the requirements of the system.

Basic assumptions of this approach were:

- performance requirements could be specified
- careful detailed pre-planning could eliminate subsequent configuration and engineering changes
- speed and efficiency of development could be maximised by selecting the contractor proposal best calculated to meet this specification, carefully planning the research and development required, and assigning the task to a 'single prime contractor'.

Although containing the essence of good project management approaches, the systems management became synonymous with bureaucracy, interference, and paperwork. Furthermore by separating the specifiers from the achievers there was, and continues to be.

a problem of setting excessive standards, particularly in high technology projects. The Atlas project introduced many new concepts but importantly established the use of testing simultaneously rather than consecutively. the risks of test failure are obviously higher with simultaneous testing which therefore forces higher standards of design and production. This effectively forces responsibility down the management line. The innovations in the management of the Atlas project were resented by the USAF senior staff and caused problems which were only overcome by the direct intervention of Congress. However, the conflict between functional organisations and project orientated organisations became clear, and continues to cause problems if not managed well.

The US Navy's ICBM project Polaris was to introduce Program Evaluation Review Technique (PERT) which was to become established as the basis for much project planning. The development of PERT was the response to a previously qualitatively reporting system where imprecise terms were used to record the programme's progress. The essence of PERT is the accurate identification of all activities durations together with a probability that the activity will be completed within that estimated time. This is then linked to an activity map which shows the inter-relationship between all activities.

In essence the CPM method follows a similar logic. Credited as being developed by Du Pont in the US, although similar work was carried out by ICI and the CEGB in the UK, CPM like PERT, uses network analysis, uses arrows to represent activities and illustrates projects as cascading bar charts. CPM was developed for construction and maintenance purposes where down time for plants or the time for construction was the information needed. The difference between the two is that PERT gives the probability of an event happening, whereas CPM concentrates on the activity duration. Figure 3.1 gives a comparison between the two systems.

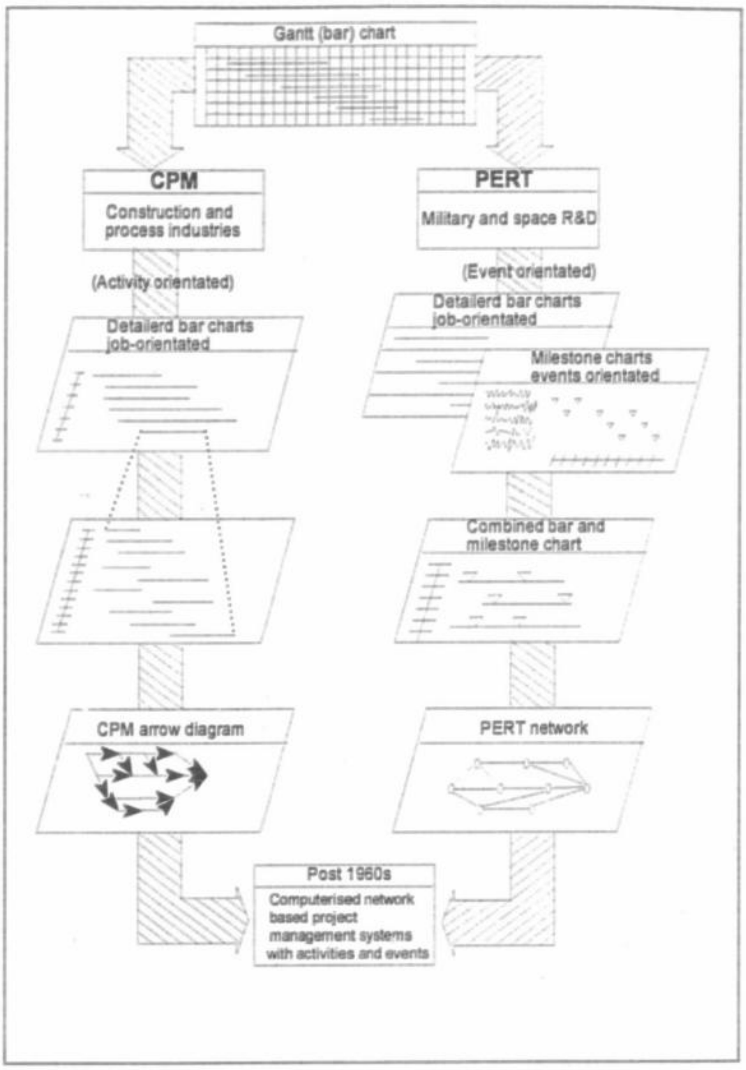


Figure 3.1 CPM and PERT compared taken from Morris (1994)

During the 1960s the most significant development for project management was the Apollo series of spacecraft and the ultimate landing on the moon in 1969. The political desire by President Kennedy to regain the lead in the space race with the USSR led to his famous declaration on the 25th May 1961, six weeks after Yuri Gagarin's inaugural space flight -

> 'I believe that this nation (US) should commit itself to achieving the goal, before the decade is out, of landing a man on the moon and returning him safely to earth'.

As there were enormous technical, logistical, administrative, and numerous other problems to resolve, the Apollo series was the biggest project ever undertaken and forced new methods and approaches to be developed. The use of matrix organisations, Work Breakdown Structures, Precedence programming, and task orientated management all contributed to the ultimate success of the moon landing in 1969. At an estimated cost of $25.5bn the Apollo project has to be considered mankind's most daring project management exercise, the lessons from which are still being learnt.

From the late 1960s onwards the use of project management has increased into numerous diverse areas, partly driven by technological advance, and partly by the apparent advantages of this specialised management approach. Of the many areas which employed project management the most important for its development were research and development projects, overseas development projects (mainly civil engineering and construction), aerospace and military, process engineering (especially North sea oil), and fast track construction. Along with the expansion in use, came the widespread realisation that project management was not the panacea for all management problems, as prestigious projects became notorious for cost overruns, delays, poor performance or cancellation. Throughout the last quarter of a century there have been innumerable projects carried out covering the full spectrum of human endeavours. The analysis of this vast collection of data has enabled academics to extract the sources of success and the causes of failure. This work is however recent, with the majority of the writing on project management being concentrated on developing the tools to be implemented, or applying the system of project management.

As would be expected from a branch of management founded primarily in the US, the majority of the writing on project management comes from North America. Here the development of ever more powerful computer based project planning software has generated a sub-field of scheduling specialists. As computers became more powerful and their size reduced, so the ability to schedule in more detail and with more complex relationships, led to a great increase in management information. The use of Graphical User Interfaces (GUI) has conversely reduced the need for highly expert computer planners. By incorporating Work Breakdown Structures (WBS) which dissects the project into ever more detailed and specific tasks, the scheduling and progress monitoring function was increasingly being associated with procurement strategies and administrative procedures. The recent introduction of relational data bases with the potential linking of Computer Aided Design (CAD) will further allow more holistic management of project information by computer with managers receiving integrated reports which cover cost, time, and specification. Yet for all the advance in the technology applicable to manage the complex and dynamic world of project management, there has been much criticism of project managements' success at achieving the ultimate objectives of bringing the project to completion on time, within budget, and to the correct performance specification. It is the causes of these problems which need addressing and to which attention now turns.

3.3 Success or failure

Before investigating the various problems which may impinge upon a project there is a fundamental question which needs to be asked. This is what constitutes a successful project, and equally what are project failures.

The simple answer to the first question traditionally involves a project which is achieved under budget, within the expected time frame and which meets all the required performance specifications. This tripartite solution leads to three areas of concern for any project, namely money, time and quality. the textbook way of demonstrating the relationship between the three is being on the points of a triangle as shown in figure 3.2.

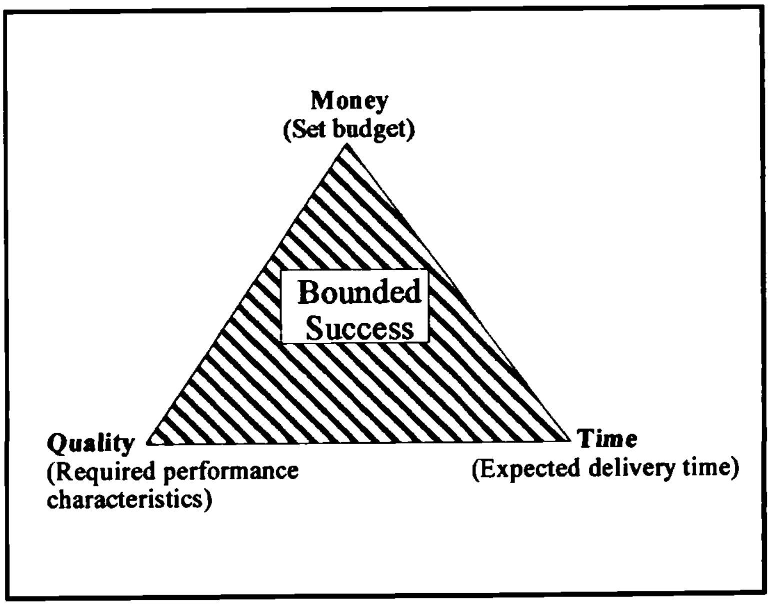


Figure 3.2 A project's tripartate objectives

According to this measurement system, projects which go above budget, beyond target completion time, or fail to perform according to specification are classified as unsuccessful.

Yet is this justified? In a study by Baker *et al* (1988), 650 projects were surveyed in an attempt to define a successful project. Their definition, following analysis of the results is

> 'If the project meets the technical performance specifications and/or mission to be performed, and if their is a high level of satisfaction concerning the project outcome among the key players in the parent organisation, key people in the client organisation, key people on the project team, and key users or clientele of the project effort, the project is considered an overall success'.

As Baker points out, the role of perceptions is important to this definition and therefore suggests the use of the term "perceived success of a project". This is an important issue as the variation in circumstance affects the judgement. For example, the early projects which developed deep water oil rigs for the North Sea cost substantially more than budgeted by the oil companies commissioning the rigs. However, as time was crucial to the work with untested technology coupled with hostile conditions; with only a short period of calm weather annually for towing the rigs to their location, the oil companies realised that cost escalation was tolerable as long as the technical specifications were not compromised and that completion times did not slip considerably. In contrast, there has been great concern for the new British Library which, although now being stocked, is being questioned over its capacity for controlled climatic storage with the possibility that it may not have sufficient suitable space. A study on computer software development projects (Financial Times 16.5.94) reported that in excess of over 50% of all projects fail to produce any useable product. Similarly, drug research carried out by pharmaceutical companies have many projects which fail. Yet the knowledge gained through such failure is absorbed and subsequently used on more successful projects.

The traditional consideration of project management as the best way of managing time, cost, and quality is increasingly being challenged as being too narrow, with the criteria for success lying outside these clearly defined areas. Particularly in the light of evidence that satisfaction with the performance of the product and the process by which that product came about are the most critical items. This does not mean that time, cost, and quality are not highly significant factors to the overall success of a project, but rather, project management needs to consider more than these three factors when attempting to provide a successful project.

A project is referred to as if it were an entity itself. This is simplistic and hinders analysis of the more interesting factors which contribute to a project's success or failure. If the issue of quality is considered in a construction context then the quality of a project is an ambiguous term. If the elements of the project are considered then there is a realisation of the diverse interests involved. The client will be interested primarily in functional quality. This will normally be seen as fulfilling the operating objectives expected of the completed project. The operating objectives may require the project to satisfy certain technical criteria, for example being water tight, but may be linked to other parameters such as time; needing a completed building by a certain time to meet seasonal demands or arranged occupancy.

The architect may see the aesthetic quality as being the most significant. Where a client wishes to express something unusual through the style of the project then the architect's training in form and vision will mean that much of the 'feeling' of the project will not be measurable until the project is substantially complete. As aesthetics is a personal issue it is likely that there will be criticism as well as praise. Design engineers will see technical quality as paramount. Structural integrity of the frame and operating capacity of the mechanical and electrical services will initially set the technical standards. Additional factors such as adaptability, maintenance, environmental considerations, lifetime costs and new technology will all influence the engineering quality with little obvious affect to the completed project.

The construction management and contractors will be concentrated upon the need to build the project to suitable standards and maintaining a system which can be easily monitored. The 'craftsmanship' of construction is the most obvious result. There are however a range of other quality issues which affect those constructing the project. Primarily there is the recent need to demonstrate 'quality assurance' through the adoption of rigorous systems of administration. The international backing of such schemes through ISO 9000 has meant the wide scale adoption of quality assurance schemes by many medium and large contractors. Other issues, particularly related to health and safety, have made construction managers and operatives consider the way the project's physical activities are executed. The result is a concerted effort by the constructors to implement a range of quality related improvements to their procedures. Most recently, changes in health and safety legislation namely the

Construction Design and Management Regulations (CDM) have linked the actual design to the safety of those carrying out the construction. It is now possible for designers to be held responsible for any injury sustained as a result of a construction operation failing because it could not be carried out safely. This new dimension will force designers to continually be aware of how their design will be built and ensure that designs are both feasible and capable of being constructed safely. This philosophy is extended formally into the physical activities on site, where a planned method of safe working is required, otherwise sanctions will be enforced.

To achieve the diverse requirements which a project implies there has been a predominance of literature which considers one aspect of project management. This is considered next.

3.4 The Techniques Approach

Within the traditional textbook teachings on project management there is great emphasis given on applying the techniques developed to manage time, cost, and quality. CPM, PERT, and increasingly relational data bases, run on powerful personal computers are seen as being the answer to managing time. Work Breakdown Structures and the use of Earned Value provide highly detailed cost information, which increasingly links the project's budget to its programme. Budget estimates are prepared by cost experts capable of integrating design information, current market forces, environmental factors, together with a host of other endogenous and exogenous variables, into a detailed budgetary forecast. Modern management practices provide the innovative administrative and management skills necessary to ensure success. Recently, the focus within project environments has been on the quality issue. From quality assurance to total quality management there has been a dramatic increase in articles and books explaining the various aspects of quality and how to obtain it. Many methods of obtaining quality are recommended. Quality Function Deployment, Taguchi methods, quality circles, Demming wheels, together with many others, have been written about (Gehani, 1993) and authors such as Peters, and Crosby have written best selling books which many in the project management field have adopted.

As these elements have received much previous attention and are included in many project management text books, the detail of how these various 'tools' of project management work will not be expanded upon in this work. What is more relevant is that despite access to all the modern approaches to project management which these various tools represent, there is still clear evidence of project failure measured in total terms, as well as in terms of time, cost, and quality. As many examples exist which demonstrate the validity of the 'tools' individually, project failure cannot be explained by questioning the functioning of these technical project management techniques.

Rather than considering a project as problem area to which a number of narrowly defined techniques are applied, the hypothesis is that the success of any project lies in the areas not covered by these 'tools'. Particularly, the factors which are seen as being crucial to a projects success are:

- The type of client
- The experience and training of the other main players (designers, project managers, technical staff)
- The way in which the project is originally configured
- The relationships and communication patterns established

This list appears from the literature to represent the 'soft' factors (Morris 1994) which do not appear prominently in the project management textbooks at present, but which are increasingly featured in the modern journal writing.

3.5 The client

A review of mainstream text books covering a range of project management applications reveals that the client's role in project management tends to be understated or simplified. Generally the literature assumes one of two options for the client's role in project management. Firstly, the client is assumed be the parent company employing the majority of the staff directly who are charged with the task of working on an in-house project. Examples are major car firms developing new models, through to electronic and other high technology producers who develop new products. The issues involved with this form of internal project management are significantly different from the 'external' project where a client employs the services of others in order to obtain a product or service. Examples of this form of project management are construction, ship building, process engineering plants and oil rigs, through to specialist computer software writing and modern film production. In this form of project management, which tends to dominate the early project management literature, the only role of the client is seen primarily as being the instigator of the project. Once a client decides to obtain some new facility there then follows, in the literature, a number of 'guides' as to what should happen. As previously stated the majority of writing appears mechanistic with various techniques used to control the various elements of the project. What is particularly noticeable is the lack of emphasis on the briefing process. Here the client's actual desires are expressed in document form which becomes the basis for all subsequent design and production. This stage should occur in both internal and external project management and the general lack of emphasis on completing the stage fully is well documented. Of the many possible examples citable Nayak and Ketteringham (1986) reveal that JVC beat Sony in the race to develop a domestic video cassette recorder (JVC with VHS, Sony with Betamax) because JVC had a far better brief before research started. Sony, although with a technically superior product (Betamax video image was clear and had superior sound quality) had failed to analyse the fundamental requirements of the VCR and only designed Betamax with a one hour tape capacity. The result was that flexibility of a three hour capacity for VHS was more appealing than the initial one hour capacity of Betamax which led to JVC gaining early market share. Although Sony improved Betamax, the delay was to prove fatal for the Betamax format.

In construction, much of the UK project management literature reflects the traditional approach of the industry where project management is seen as only being significant in the post design stages. Thus project management of the design stage is not investigated in depth and little is said on how this vital stage should be managed. One noticeable exception to this is the work of Stasiokwski & Burstein (1994) who detail a range of techniques and systems which a design firm can use to manage its contribution to a project. The North American approach to construction is better in respect of the commercial approach taken by all concerned, notably the architect who integrates design and cost control. This is reinforced by a tradition of standardisation of specification and design and a high use of standard materials and construction methods. This difference has been dramatically illustrated by a report, produced by Lynton PLC (1993), the property development division of BAA, which showed a 32% saving between functionally similar buildings constructed in the USA and UK. Part of the cause of such increased costs is the complex contractual route which clients are traditionally forced to adopt. The protracted negotiations between the receivers and potential buyers for the Swan Hunter ship yard during 1994-5 illustrate how the contractual conditions which apply to a particular project (a frigate for the MoD) can have dramatic affect (the prospective French buyers could not agree a price based on the contractual conditions applied, forcing the ship yard to close).

Clients who require external project management expertise are increasingly using 'partnering' as a possible solution. There are two types of partnering; strategic partnering or project partnering. The principles for the former are simple, clients have favoured consultants, etc, whom they favour for all similar work. For the latter, no long term commitment is made but, for the project being considered, a framework is established which mutually agrees a 'code of conduct' for all parties based on reasonableness and trust. This is underpinned by a formalised conflict resolution system. These additional management tools are in clear addition to the standard contract which, in partnering terms, is seen as being of less importance and is used as a last resort. An important element in this approach is the development of mutual trust which is created and fostered by all sides. Rover cars entered such a 'partnership' with SDC builders for the building of new R&D facilities. As Brian Fox, the managing director stated in *Building* (5.8.94) 'I believe that if someone trusts me, then that places a greater onus on me than any contract ever written', (p.33). Although not a common occurrence in the UK Marks and Spencer PLC have been in a partnering agreement with Bovis since 1926. Yet it is abroad, especially in Japan, that partnering is the norm. Not only in construction but in virtually all of Japanese economic society long term relationships are built between companies involved in project management. These relationships have continually proved to be effective at reducing time and cost with little impact on quality.

For many commercial clients the frequency of repetition will be the key factor. For those who are frequent purchasers then there is clear incentive to enter such strategic arrangements.

For those clients who are infrequent and one off purchasers there is not such clear benefits for strategic partnering but project partnering can be highly successful. A report by the University of Westminster (Barlow, 1996) records a number of partnering arrangements, one of which for the Selfridges department store in London, was a project partnership between the client and the contractor. The results of the project were highly successful, with a major refurbishment being achieved within budget and crucially on time to meet the Christmas trading needs. Both parties found the experience extremely beneficial and would choose a strategic arrangement if the parent company, Sears, permitted it.

In situations where partnering is not used there is still a need to ensure that projects are managed by personnel who have the client's best interest at heart. This may mean employing directly the services of a project manager or even a project team who oversees the project. Where this is not done, there are well documented examples of projects where the outcome was a failure from the clients viewpoint. The UK public sector is notorious for this with many projects being the responsibility of many departments with no clear point of authority. Similarly the US development of the F-111 jet fighter proved to be far more expensive and take longer than originally intended because of conflicting interests from different parts of the USAF.

3.6 Experience and training of other main project players

It follows that a project's outcome will be correlated with the abilities of those responsible for its key elements. The use of designers familiar with the specific client's needs is crucial. Technically proficient experts on cost, planning and other specialities are also necessary, but not sufficient factors. In addition, there are management and leadership functions which need to be provided. These qualities are more difficult to verify when selecting candidates, either companies or individuals, yet the impact made by these factors can be crucial. Effective management, as demonstrated through company systems and procedures, provide the project structure. Methods of communication, management style and project atmosphere are all directly affected by the management of a project. Similarly, and as crucially, the leadership qualities of the key players on any project can have dramatic results. The case of the channel tunnel provides a clear example of the way in which the personality of a key player can have enormous impact. This is especially so where the financing of the project comes from the increasingly global finance markets. Although seemingly naïve, institutions place great faith in the individuals selected and projects can, and indeed have been, cancelled because of personality conflicts. More than this, the right sort of leadership for a project can intercept problems before they become serious, can provide the motivation to keep the project to its objectives and can seek out ways of improving the project so as to provide enhanced benefit to those involved on the project.

The qualities required depend upon the project in question. Emmons (1979) writing in relation to the petro-chemical industry noted that even within that sector 'each project requires a different, or special, project management approach'. The very diversity of projects therefore requires generalists who can quickly adapt to the specifics of individual projects and tailor their approach accordingly.

The difference between project management and other forms of management relates to the management of time. Vinton (1992) stresses the importance of temporal forces when managing time. Vinton follows Hall's (1969) work on monochronic and polychronic styles of task management. Monochronic styles are where a person focuses on one thing at a time, separating activities in both time and space. Here importance is placed on schedules, tasks, and procedures. Polychronic styles, focuses on several things at a time. Importance here is placed on people and relationships and the completion of transactions over rigid adherence to a preset schedule. Hall explains how north European cultures (including the UK and USA) tend to be monochronic, whereas Latin American countries tend to be polychronic. Vinton notes the following

> 'A person who moves from a departmental setting to a cross functional team enters the group with predispositions to act in particular ways. This individual behaviour set is a result of at least two sources of influence - first, the set of knowledge, attitudes, beliefs, and expectations created by the technologies, tasks, and roles that existed within the former work setting; and second, by his/her personal background'.

The affect on a project's outcome of the training and experiences of the key players is therefore vital. Part of this valuable experience is the understanding and insight gained from staying with a project for its full duration. This policy is not however widespread in project management. In the majority of projects, with the exception of very large and valuable projects, there is a tendency to move staff frequently, denying the possibility of individuals seeing the full project lifecycle. This problem has been particularly prevalent in the US defence industry as noted by Fox (1988) with managers not staying with projects as their career progression moved them continually onward.

3.7 Project configuration

The environment in which a project is set and the way in which it is begun can have a dramatic effect on the project outcome. The timing of the project, media attention, political factors together with a host of externalities has proven crucial to many projects. The increasing role of the community, in the form of environmentalists, action groups, and specialist pressure groups have to be accounted for in the way a project is configured. The US's Supersonic Transport plane (SST), a civil airliner to rival Concorde, was aborted through public pressure which was originally dismissed by those concerned with the project. Similarly the East London river crossing was withdrawn after an extensive public enquiry, which ended in the High Court, threatened an area of ancient woodland. In the private sector the construction of over 15 US nuclear power stations has been aborted due to external pressure about safety and operating standards, in some cases this was forced through a refusal to grant operating licences or obtain insurance cover. The timing of a project can cause serious problems, with the recently completed Chelsea and Westminster hospital proving to be a major drain on the Regional Health Authority's (RHA) budget as the funding for the project failed to be achieved when the property market in London fell dramatically, which reduced the value of the portfolio of properties the RHA were hoping to sell to raise finance.

3.8 The complexity of managing the design stage

As covered in chapter rho, the design stage of a project is crucial to the overall success. In product development projects there has been much written on the use of concurrent or simultaneous engineering (see for example the work of Clark and Fujimoto 1994, Pugh 1991) and there are many tools and techniques recommended to assist in producing better products more cheaply and more quickly. These include quality function deployment (QFD), failure mode effects analysis (FMEA) and process analysis. McLinn (1994) combines all three of these techniques to assist in the improvement of the product development process. The original work of Austin *et al* (1994) in developing a model for planning design activities led to the development of a computer simulation programme which can model the design activities and predict the likely outcome (Austin, Baldwin, Thorpe & Hassan, 1995). Such an ability to accurately forecast likely design outcomes, in terms of fully completed, conditionally completed or areas of the design requiring additional resources, allows project managers responsible for the early stages to plan a strategy which may affect procurement, sequencing or the employment of additional resources.

3.9 Communications and relationships established

The various factors outlined above all build into a complex picture of a project. Clearly many projects will be relatively straightforward and will be completed successfully. It is, however, impossible to guarantee this outcome at the beginning of a project. Indeed it this very uncertainty of outcome which forces the vast majority of projects to be managed under contingency conditions. Where the contingencies are not adequate, then there is the potential for project failure.

Projects are complex and dynamic, requiring many tasks and factors to be processed concurrently. This complexity has required a highly organised response from those involved. Project organisations, made up from many different functions, departments, and/or organisations have evolved into complicated structures. The use of matrix management, where functional responsibility is spread over a number of projects or sub-projects leads to the creation of intricate communication channels which themselves have to be effectively managed. The Apollo space series demonstrated how beneficial this communication management can be, with attention to paperwork providing the right parties with the right information at the right time. Problems with communications often lead to design changes, increased cost, and delays. There is a need to consider at the earliest stage the minimum amount of communication necessary for effective management. Often the communication required can simply be the routine updating of current situation. Critically, the regular involvement of the various parties can provide major benefits to any project.

The final area which needs consideration is the relationships between the various parties. Often relationships start to sour as the project goes wrong, but the question is increasingly being asked as to whether the project goes wrong because a good relationship was not fostered from the beginning. The involvement of many factions on any given project will inevitably lead to an array of hidden agendas. Reputations, egos, politics, incompetencies and mistakes will all have a detrimental effect on the project if allowed to become significant. Yet, where the project's objectives become the paramount motivating factor behind the main players, then the outcome can be very different. Again the Apollo mission had the full support and conviction of virtually all those involved. From President Kennedy, through Congress, to the various technical sections of NASA there was an overwhelming drive to make the project a success. This desire overcame the tremendous tragedy of the deaths involved with the Apollo 7 disaster and ultimately achieved the astonishing feat of placing, and returning, men on the moon. The Manhattan project, North Sea oil exploration, and a host of other projects spanning the full spectrum of project management indicate that astonishing results are capable of being achieved when all the factors are in place.

3.10 The Structural Effects of Project Contracts

When a project requires the contribution from players who are not employed by the same organisation there has developed a highly complex framework of legal contracts which set out the roles and responsibilities of the those concerned. As projects have become more complex so there has been a tendency for the contracts to become ever more detailed and specific.

In the UK construction industry there are many forms of contract employed which range from simple verbal contracts and single sheet contracts for small works, through to complex documents requiring specifically trained legal experts to compile and interpret them. As modern construction projects pose a potentially large risk for clients, there has been much emphasis placed on establishing contracts which attempt to allow for all possible eventualities. The sheer complexity of construction projects has forced clients and other project players to adopt forms of contract which could easily be interpreted by other construction industry players and, if necessary, the legal courts. The need for such standardisation resulted in the establishment of the Joint Contract Tribunal (JCT) which produced 'standard forms' of contract. The range of standard JCT contracts reflect the variation in procurement routes which are in widespread use in the UK. From the standard contract which is often referred to as 'traditional' contracting, through to the management forms of contract used for construction management and management contracting, the JCT has established itself as the basis for the majority of contracts used in the construction industry. Due to the diversity of construction projects an increasing number of modern projects have used amendments and additions to the basic form of contract which represent the changes in emphasis and management within the construction industry.

As the level of uncertainty involved in the performance of construction projects is high the contract forms a key part in defining roles and responsibilities. Although managements' function is to endeavour to produce the desired product given a range of inputs, the management operate strictly within the terms of the contract. The result of the emphasis on contracts has been to dictate the approach to project management. It is obvious that astute parties to the contract will not intentionally violate contractual conditions, but also the contract is frequently used to establish the guidelines of operation for the project. Masterman (1992) reviews all the major forms of contract through the use of 'procurement systems'. These systems, such as design and build, offer different benefits and problems to the client and place varying responsibilities on the project players. These variations, together with large sums of money involved, force the management of projects to follow clearly defined paths. When projects go significantly wrong it is through the contract that redress is sought. Franks (1991) examines how the contractual arrangements currently employed have developed together with a analytical system which demonstrate each procurement system's particular strengths and weakness. From this approach it is clear that the contractual framework is fundamentally linked to the form of procurement system, which in turn dictates the management style found on any project. The publication of the Latham report (1994), which investigates the lack of improvement in the performance of the construction industry concludes that it is through changing the contractual side of construction that significant improvement will be made. Yet evidence provided by the poor performance of the British

Property Federation's form of contract, set up to address many of the common faults found in construction, suggests that this form of solution may still not address the issues.

The focusing on the terms and conditions of the contract, especially during periods of falling tender prices, demonstrates a more deep rooted problem. The various players on a project have traditionally been trained by a system which dictates specialisation without generally allowing for the understanding of others contributions. The increasing 'professionalism' of the construction industry where membership of a number of professional institutions was required has led to a separation of skills and differences between perception and expectation. This specialisation of the professions has occurred within the context of commercial rivalry where increasingly, project membership is secured through lowest bid tenders. The result is that there is little facility for the project members to become teams. Rather, they remain, at best, coalitions which will quickly degenerate into factions when problems arise. As major problems do arise, the result, as seen on a number of major public projects, can be acrimony and litigation.

As the punitive sums involved when a breach of contract occurs can be vast, there is considerable emphasis placed on monitoring the contract. Indeed the role of the modern quantity surveyor is increasingly to ensure that the conditions of contract are enforced, as well as provide the traditional tasks of ensuring fair payment is made for completed work. Furthermore, the damages which can be obtained for a serious breach of contract have led to complex insurance and warranty schemes being developed by financial specialists. The range of insurance cover, from professional indemnity insurance of professional services, through to collateral warranties and project specific insurances, introduce yet more managerial constraints. Linked to this area is the use of third party guarantor bonds raised to cover the trade contractors in case of insolvency. These added financial instruments act as further constraint to the project management's scope of operations and can lead to additional bureaucracy.

3.11 Review of Cases

Within the construction industry there is relatively little detailed modern case study evidence which sheds any light on the complex areas of management. Although the industry attracts much media attention and has gained a reputation in the UK for being generally inefficient and expensive, there is little objective evidence. The National Audit Commission has produced a number of reports which examine publicly funded projects including the new British Library, the prison building programme, and highway maintenance. In addition there have been a number of case study based theses and reports produced by Schools of the Built Environment, including University College London, which have examined the key management issues involved on a range of prestigious projects. By considering these projects as a group it is possible to begin to understand a pattern of outcome. The projects considered range from the Sheffield Arena (Luckman, 1994) to the Channel Tunnel (Winch, 1994) and cover purely private funded projects such as Glaxo (Usmani &Winch, 1993), Waterloo Terminal (Sim, 1993) through to purely publicly funded projects such as the British Library (N.A.C., 1990). All the reports cited, detail varying complex reasons why the project studied failed to be an outright success in textbook terms. The general problem areas of these projects could be classified under the headings of finance, externalities, management, and procurement. From the complex financial constraints and externalities of the Channel tunnel, through to the lack of early client control at the British Library, the reasons for major problems occurring appears to be as diverse as the types of project. Yet there are some broad brush statements can be made which apply to all projects and, which although sounding simplistic, form the basis for any successful project.

The first area to be considered should be the financing of the project. As construction projects are extremely expensive, considerable effort should be spent on considering the financial plans. The British Library for example had its construction timetable effectively set by the government imposed annual spending limits. The arbitrary nature of the split into phases and sub-phases has been partially responsible for the confusion which has reigned. The lack of certainty in raising the necessary finance for the Sheffield Arena led to an unstable client structure which partially caused a culture of ambiguity and change to the project which jeopardised the completion date. The enormous complexities of funding the Channel Tunnel resulted in a range of policies primarily designed to place risk against other project coalition members to the detriment of the project.

The involvement of third party financiers leads to the next area of potential problems, namely the external environment in which the project operates. Of particular importance will be the state of the economy throughout the lifecycle of the project, the dominant political dogma, and cultural and technical changes which are likely to occur. The Channel Tunnel's spectacular increase in actual cost against projected cost was linked strongly to the dramatic boom of the late 1980s. Although other factors also substantially increased costs, there was an underestimate of the effect of the business cycle on the tender prices submitted. It should be noted that the universal nature of the expansion in the economy during this period also allowed the financiers to forecast increased revenues and obtain further investment finance. It is open to speculation as to the reaction of the same financiers if the timing of the project were not to have coincided with such a powerful surge in the economy. The political atmosphere can affect projects' success through a number of ways. For public projects there has been a dramatic change in attitude. The selling off of the PSA, the encouragement of privately financed 'public' projects through concessionary contracting and the Private Finance Initiative (PFI) and the change to more innovative forms of contract, have caused fundamental changes to the largest projects. In addition there is the affect that changes to legislation, particularly planning laws, can have. A current example of such changes is the proposed curbing of approval for out-of-town shopping centres. This proposed change will have a direct affect on private development companies as well as encouraging urban regeneration of city centres. The last external factor which can have substantial influence on a project is the affect of the statutory authorities who have jurisdiction over a project. An excellent example of the affect that such a body can have is the involvement of the Fire and Civil Defence Authority's requirements for the Sheffield Arena. Although involved in the development of the design for the arena, the design was required to be formally submitted for approval by the FCDA. The FCDA required changes to be made to the design to ensure safety of the patrons during an evacuation. These changes, issued on the recommendations from the enquiry into the Hillsborough disaster created substantial problems and jeopardised the completion of the project. Eventually a compromise on the late changes was reached, but this caused increased cost and delayed the completion date.

The correct management, in terms of skills, organisation, and staff numbers have been cited in various reports as being crucial to a project's successful outcome. The National Audit Commission's study into road maintenance found that staffing levels varied greatly regionally for similar projects with both under staffing as well as over staffing. The Channel Tunnel saw substantial reductions in management staff in order to streamline the organisation in response to criticism over undue bureaucracy. The novelty of the new Waterloo terminal required different management skills from those available from British Rail's large and well established management organisation. Especially important is the correct involvement of the client's management. Unless the client frequently constructs there has been a tendency to pass responsibility onto other representatives. This approach has led to many problems arising which could have been avoided. The lack of involvement of the Office of Arts and Libraries in the early stages of the British Library led to increased costs, delays, and the development of ineffective management control. Conversely the full involvement of the UK supermarket managers in the development of the management of their new retail facilities continually reduces delays and design changes.

3.12 Conclusion

The range of influences on project management, from external agents and factors, to perceived wisdom in textbooks, is considerable. The complete matrix of all inputs and outputs, for even a simple project, would be large, with a corresponding variability of success. To achieve such success for projects which are, *inter alia*, complex, therefore requires a clear sighted approach. The gap analysis, introduced in chapter two, provides such clarity. It Allows the project to be considered from the client's viewpoint and enables the myriad of issues to be grouped into stages which mirror the chronology of the project. The traditional view of project management would focus attention on the gaps in conformance and execution, as can be seen in figure 2.7- the latter stages of the project, yet as has been discussed both in the previous chapter and in this, the critical success factor requires the project to be considered as a whole.

The next chapter examines the contribution to this holistic approach posited by the new management area of Business Process Reengineering.

Chapter Four
Business Process Reengineering

4.1 Introduction

Since the work of Frederick Taylor and the development of 'scientific' management there has been an ever increasing search to find solutions to the problems which have hindered businesses from achieving optimum efficiency. In recent years, particularly since the early 1980s there has been a dramatic increase in non-academic business management books written by a variety of authors who espouse the virtues of particular management styles, tools, and techniques (for example see the various works of Peters and Waterman, Crosby). Many of these authors developed a core theme which they believed to be central to the problems being faced by developed western companies. Of the various recent topics the first, and probably the most expensive in terms of capital outlay, was the move to information technology. Once installed, the vast majority of companies failed to gain dramatic improvements in operating efficiency or reduction in unit cost which many had been led to expect. The discovery that the new technology was not the solution led to more wide ranging searches for improvements. The results of these searches can be grouped under two headings. Firstly there was a variety of solutions generated from the study of foreign competition, most notably from the Japanese. Closer examination of the Japanese example in particular led to the introduction of numerous elements of other styles of management including Just In Time inventory control, lean production, Taguchi methods, Kanban production control, and many more besides.

The second area is the Quality movement, some of which comes from studies of foreign countries, but the majority have been developed to meet the perceived need of western countries. Initially, quality was concerned with quantitative measurement of production and was developed as a control tool. Many statistical tools were developed to give highly detailed analyses of production variations which could be used to prevent unsatisfactory products. This form of quality control was restricted to industries whose performance was easily quantifiably measurable and was applied to the product by the producer without regard for the customer. Apart from being only a partial view of quality, statistical quality control was not readily applicable to the many service industries in an economy like the United Kingdom.

The introduction of Quality Assurance was heralded as being a more pro-active form of administrative control which would ensure uniform quality. Although a major topic in itself the essence of QA is that firms establish a rigorous system of procedures which are followed continuously. Once firms have established such systems, third party assessors are used to certify that system and a universally recognised award is given. Firms with the award are then audited periodically to ensure that the system certified is subsequently being used. The practical problems with QA was, and is, that many firms find it expensive to operate, and more importantly, feel that QA provides a 'straight jacket' in limiting their operating procedures.

A third and different area of quality was the introduction of Total Quality Management (TQM). In contrast to the two previous quality programmes, TQM is a philosophy for managing firms which was developed from US and Japanese experience. Essentially, TQM is the continual search for improvements to the way in which firms operate. As such TQM prescribes a number of management tools which can be used to locate such improvements. The use of teams and quality circles is an example of such tools, and also demonstrates the emphasis on worker participation. TQM requires that all employees feel they have a part to play in improving their contribution to the company. The company as an entity sets standards which are continually strived for, and hopefully bettered. These goals ultimately lead to the generation of 'mission statements' which succinctly state the companies objectives.

The widespread adoption by many UK businesses of many of the aspects of the items set out above has generally not led to the dramatic improvements implied in much of the literature. Whilst there have been success stories and no doubt a great deal of initial positive motivation, there has been widespread criticism of the management solutions considered. A key point of the criticisms is that the methods tend to address only part of the overall problem. It was with increasing realisation that attention began to turn to other remedies.

4.2 The background to Business Process Reengineering

In an attempt to seek business solutions to business problems, companies began to consider the fundamental issues which were the key to their operating success. As the pioneering companies concerned were using their own initiative and were prompted by individual circumstances there was no unification to approach and indeed, it is only recently that writers have sought to classify pioneering companies who carried out what others now term 'Business Process Reengineering' or 'Business Process Redesign' (BPR). This point is important as Business Process Reengineering has grown into a subject of its own from the activities of a number of disparate companies from around the world.

Whilst there are many similarities between BPR and TQM there are equally important differences. Both concepts are based on the premise that the business process is the key to success, however, as noted by Gulden & Reck, (1992) they differ in the motivation, technique, objective, result, and the business circumstances in which they are applied.

The antecedents of BPR are more than just the quality issues. The concern of competitiveness in general has been a force in developing BPR. As the speed of major improvement is a key element of BPR western companies have adopted BPR as a way of quickly catching up on industry or world best competitors.

A second factor is the changing realisation of how organisations are structured. Decentralising, horizontal management, case workers, and teamwork are all forms of organising work groups or companies which challenge the traditional pyramid organisation structure. The use of these new forms of structure inevitably leads to a re-evaluation of work structure and a move towards process orientation.

To enable the new organisational structures to operate in a competitive way there has been an increasing dependency on information technology. The ability to communicate complex data over geographically separated locations effectively has been crucial to increased effectiveness and competitiveness.

The above have been incorporated within the context of operations management which has drawn upon the issues of quality, customer service, time-based competition; especially of new product development, and cost management. The citing by the BPR authors of Clarke and

Fujimoto, Juran, and Womack indicate the influence of the operation management school on the more widespread area of process innovation.

4.3 The Concept of BPR

The seminal works on BPR (Hammer and Champy 1993, Johansson *et al* 1993, Davenport 1993) are all designed to appeal to practising business people and follow in the trend of 'airport lounge business books'[1]. Yet the authors are business school based and have produced previous work in academic journals (Davenport and Short 1990, Hammer 1990). The basis for all these books is case study evidence gathered on firms which have carried out either partial or total BPR. Companies which are frequently cited include Rank Xerox (US and UK), Texas Instruments (UK), Ford (worldwide), Baxter Healthcare (US), National & Provincial (UK), Mutual Benefit Life Insurance (US), AT&T (US), and British Telecom (UK). By applying the framework of BPR to the evidence provided by the various activities of these companies a framework for BPR has emerged.

BPR was defined by Davenport and Short (1990 p.11) as the 'analysis and design of work flows and processes within, and between, organisations'. The key to BPR is the emphasis on processes which Davenport (1993) defines as 'a specific ordering of work activities across time and place, with a beginning, an end and clearly identified inputs and outputs: a structure for action'. All the authors concentrate on explaining the attributes of processes. An important distinction is made between the functional hierarchy of established businesses and the way in which process orientated businesses will operate. This introduces the important concept of organisational design, reward and incentive schemes, management involvement, and the use of information technology. All of these items have been addressed individually previously, in either business or academic literature. Yet it has only been recently generally understood that by combining the management approaches provided by the use of new management tools such as just-in-time inventory control, with a process based philosophy, and by having the senior management resolve to undertake a fundamental reevaluation of the business, that major improvements in business dynamics become possible. The impression

A term used by various commentators to denote the quick fix format and dramatic style of business management book often found in airport bookshops and similar given by media reporting of BPR is that it is a revolution sweeping the business world. Behind the rhetoric is, however, the documented evidence of individual cases of BPR going back to the mid 1970s.

4.4 The Reengineering Process

The actual theory behind BPR is not yet fully agreed however in simple terms it can relatively easily be explained. Figure 4.1 demonstrates the basic BPR approach.

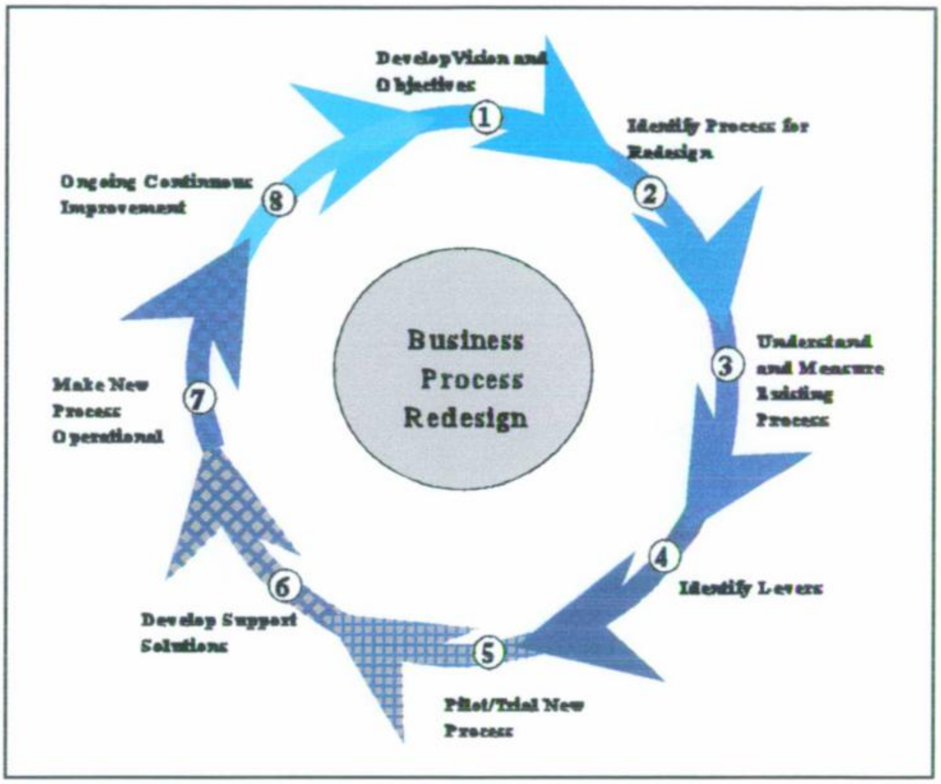


Figure 4.1 A model for BPR (adapted from Butler,1993, p.4)

1. Develop vision and objectives

The company needs to undertake a careful review of what is expected from the redesign. The essential feature of redesign exercises is that they attempt radical change. This may affect one or more of the aspects of the business, cost, speed, head count, quality, or market penetration. The fundamental nature of the review which establishes the vision or objectives is not a quick or easy task, with commitment required from the senior management in order to place enough resource into this initial stage. Although the length of time taken to achieve this stage will vary according to the individual circumstances, case study evidence indicates that in the larger and more complex organisations such as IBM and Xerox this stage has taken between 6 and 18 months.

2. Identify process for redesign

The understanding of the business as a series of processes will be the key to the redesign exercise. The number of processes identified will vary, again according to the individual business, yet it possible to reduce complex businesses to a relatively small number of processes. Table 4.1 lists the key processes for IBM for example.

IBM
Market information capture
Market selection
Requirements
Development of hardware
Development of software
Development of services
Production
Customer fulfilment
Customer relationship
Service
Customer feedback
Marketing
Solution integration
Financial analysis
Plan integration
Accounting
Human Resources
IT infrastructure

Table 4.1 IBM's core processes (Davenport, 1993, p.29)

When considering the redesign exercise it is important for the business to distinguish between the core processes and the secondary processes. The key distinction between these two is the value added by the process for the customer. The customer can be internal to the organisation as well as more obviously external to the company. The categorisation may well not be as obvious as first expected. Many aspects of the administrative activities of the business may be included in the value adding processes of a business, and previously high profile sections, such as accounts can be seen as adding no value. This distinction has been extensively explored by Michael Porter whose use of the value chain not only introduces the internal distinction in firms, but also conveys the importance of suppliers and distribution channels. Porter's view of the how a company's internal activities relate to the external environment is shown in figure 4.2. Porter's work should be seen as being one of the fundamental basis on which BPR is based.

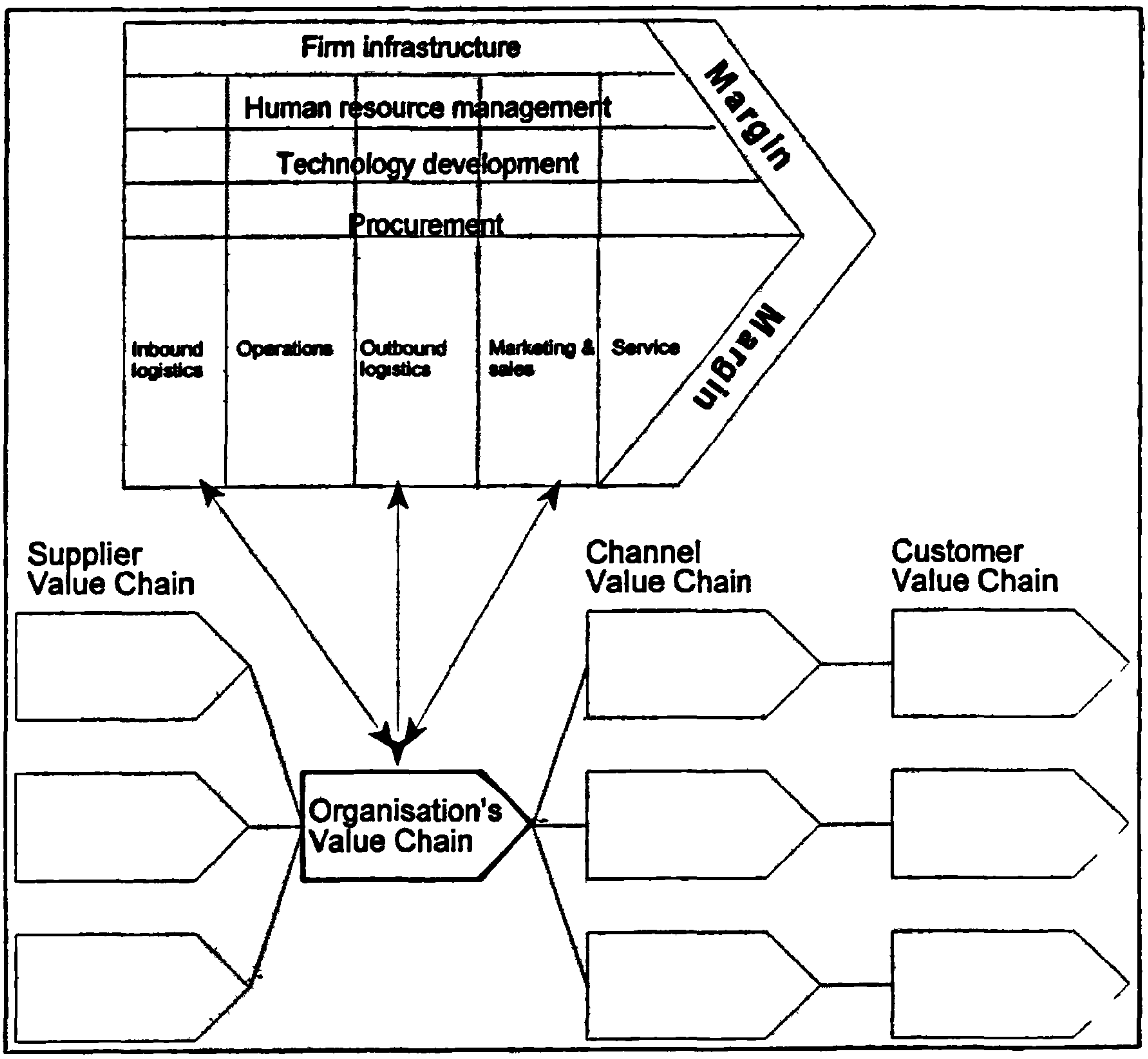


Figure 4.2 The value chain. Adapted from M. Porter, 1985

Figure 4.2 illustrates how Porter defines the activities within an organisation and relates them to the value chains of external organisations and the customer. His grouping of activities under titles such as *inbound logistics* views separate operations such as materials handling, stock control, transport, etc, as part of value adding process. This has been adopted as a central element of BPR.

3.Understand and measure existing process

The establishment of an initial set of target improvement levels in the objectives stage requires a measurement to be taken of the existing process so that comparisons can be made. Often it is this objective evaluation of current performance that provides a major incentive to continue the redesign endeavour. It is frequently reported that when an existing system is measured by, for example, tracking the progress of a particular item from order to delivery, it is reported that for the majority of the time the item is idle either awaiting some not critical activity or due to administrative delays. Once this form of evidence is presented, it focuses the redesign activities to ensure that all bottlenecks are designed out of the new process. Where observation is not possible there exists ever more complex computer modelling programmes (SimView for example) which are used to evaluate new processes, demonstrate the effects of altering current processes and monitoring pilot process redesign projects.

4. Identify levers

The levers are those key areas which will be initially focused on and, through changing, will allow the benefits of BPR to take place. Much of the literature (Davenport, Hammer) focus on the role of Information Technology in this regard. Whilst it is undoubtably true that the use of shared databases and the networking facility offered by modern communications is key to the simplification of many processes, it is worth remembering that one of the main bodies behind the push for BPR are IT consultants and hardware and software design companies. This same group were responsible for the widespread adoption of centralised mainframe computers during the 1980s with all the predicted (but largely unfounded) improvements (Financial Times 28/6/94) to business effectiveness which has cost many western companies large amounts of capital investment. There is a significant divergence between the original authors of BPR and an increasingly large number of the business community to whom the BPR ideas have been conveyed. 'People are getting bogged down with incremental improvements to what *is*, rather than thinking creatively about *what ought to be*' (Financial Times, 26.4.94). Surveys carried out by both the Financial Times (Price Waterhouse-Financial Times 28.6.94) and the US based management consultant CSC Index (1.7.94) suggest that the main reason for embarking on BPR programmes is to reduce costs and staffing levels. Indeed cynically BPR has been defined as Big Personnel Reductions!

5. Pilot trial new process

The introduction of truly radical new processes to a business should be expected to cause initial problems as the people implementing the new process will have to learn a new operating philosophy and attempt to integrate the new with the old and established way of operating. Indeed the risks of introducing such new process orientated approaches has been likened to "rebuilding an aircraft in flight" (FT 28.6.94). There is much logic in introducing trial or pilot schemes before widespread implementation. Not only does a limited introduction reduce the risk and potential cost of failure but more importantly, the pilot scheme will enable the company to communicate the potential advantages to the majority of the staff for whom the new structure will be strange and potentially unsettling. This policy can be extended to a marketing opportunity by the parent organisation for its suppliers, distributors, and customers. The importance of pilot tests illustrates the two tier approach to BPR which has become evident. The simplest form of BPR is to concentrate on key sub-processes which are reengineered in an environment in which the majority of the company remains fundamentally unchanged. Surveys in the Financial Times indicate that the large number of US and UK firms who report to be undertaking BPR or plan to in the near future are, at best, attempting this sub-process BPR. More often they are using the term incorrectly and are merely improving their existing operating standards. The complete reorganisation of the *whole* company's function and its external relationships is at the core of true BPR.

6. Develop support solutions

As a change to process based operations takes place there will need to be a range of support areas which not only ensure the new systems success, but also creates the possibility for future improvements. These support areas include the development of teams, incentive and reward schemes, future investment planning, and the development of good external relations with reliant organisations.

7. Make new process operational

This is possibly the most difficult stage to ensure success in, yet in principle the easiest to talk about. As the key process or ultimately the organisation itself fully adopts a process orientated approach there will be a need for continual reinforcement from senior mangers so that the transition does not confound the staff who will witness profound changes. In many organisations major BPR programmes have been associated with job losses or changing functional responsibilities. The affect of these clearly evident changes on the workforce can undermine the benefits of BPR. However if successful the new orientation should prove to have a dramatic affect on the performance of the business. Of the many cited examples of successful BPR some are the National & Provincial Building Society which worked during the 1990s to become a 'horizontal' company with no formal organisation hierarchy; IBM Credit reduced the time it took to approve and issue financing deals from over a week to under four hours; In Dallas, an AT&T unit which makes custom-designed power supplies for personal computer manufacturers cut its design-to-delivery cycle tenfold since 1991 from 53 to five days.

8. Develop continuous improvement

Once achieved, a BPR exercise requires constant attention to seek out new ways in which to improve the process. Companies which commit themselves to BPR will have to continue to seek improvements as competitive pressures will lead to advantages gained through BPR to be eroded over time. As BPR requires those involved to think outside the normal frame of reference in order that they establish process based operations, it is increasingly found that benchmarking of direct and non-direct competitive organisations is taking place.

4.5 Benchmarking

Whilst the obvious comparison would be between companies operating in the same market, the difficulties in establishing how direct competitors maintain their leadership position forces companies to look at other areas of operation. The ability to establish useful insights from non-direct competitors requires careful study and is expected to be a lucrative area of research by management consultants and research organisations. A reported example of the sort of unusual comparison which has been carried out is the study of the procedures used by the Indy 500 pit crews to carry out a pit stop. This research was conducted by South-West Airlines who were looking to improve the turn around times between flights for their aircraft. The lessons learned allowed South-west to reduce the turn-around time from 30 minutes to 15 minutes.

The benchmarking stages of of planning, analysis, integration, action, and maturity identified by Camp (1989) are broken down further in figure 4.3

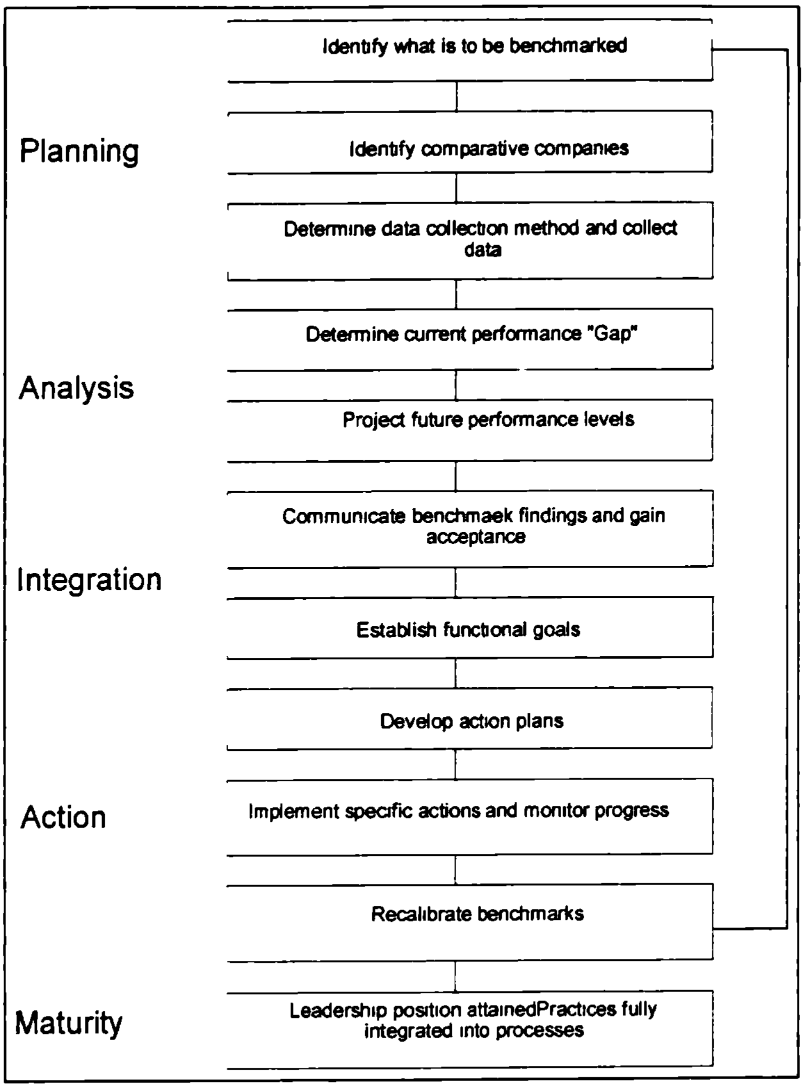


Figure 4.3 Benchmarking stages, (Source: Camp,1989, p.17)

Benchmarking is generally acknowledged as first being implemented in 1979 by Xerox in the USA. The logistics operations of Xerox were extensively benchmarked, ultimately against L.L. Bean, a mail order goods company. The exercise began with a full investigation of general industry procedures, trade literature, and possible alternatives for comparison. After careful consideration of industries utilising similar procedures as those at Xerox, contact was established with L.L. Bean and their cooperation sought. A detailed study of L.L. Bean's operations was carried and the data carefully analysed. It is during this stage that the opportunities for BPR are present. By thinking outside the established mind-set with a focused objective, major changes to operations can be considered.

4.6 An Example of Business Process Reengineering

The following case study, adapted from Davenport (1993), itself based on a Harvard Business School case study sets out the main issues involved with Business Process Reengineering.

The Distributed Systems Manufacturing Group (DSM) is a producer of network products within the Digital Equipment Corporation (DEC). It employed approximately 1,100 people during the mid 1980s and was located in the US (headquarters and four engineering groups in Boston, production in Maine), Puerto Rico, and Ireland. During the mid 1980s growth of this division was exceptionally strong, running at between 40-60% in the period 1987-89, with expected revenue of $1.5 billion by 1990. The new head of DSM, a highly motivated manufacturing based manager, selected a team who would dramatically improve the performance of the division. They developed a five year strategic plan based on three key processes: managing supply and demand, manufacturing and new product development. The plan called for manufacturing cycle time and time to market to be reduced by 50% and new product introductions to be tripled. The plan created a vision of a "virtually integrated enterprise" and was termed the "End Point Model". This is shown in figure 4.4.

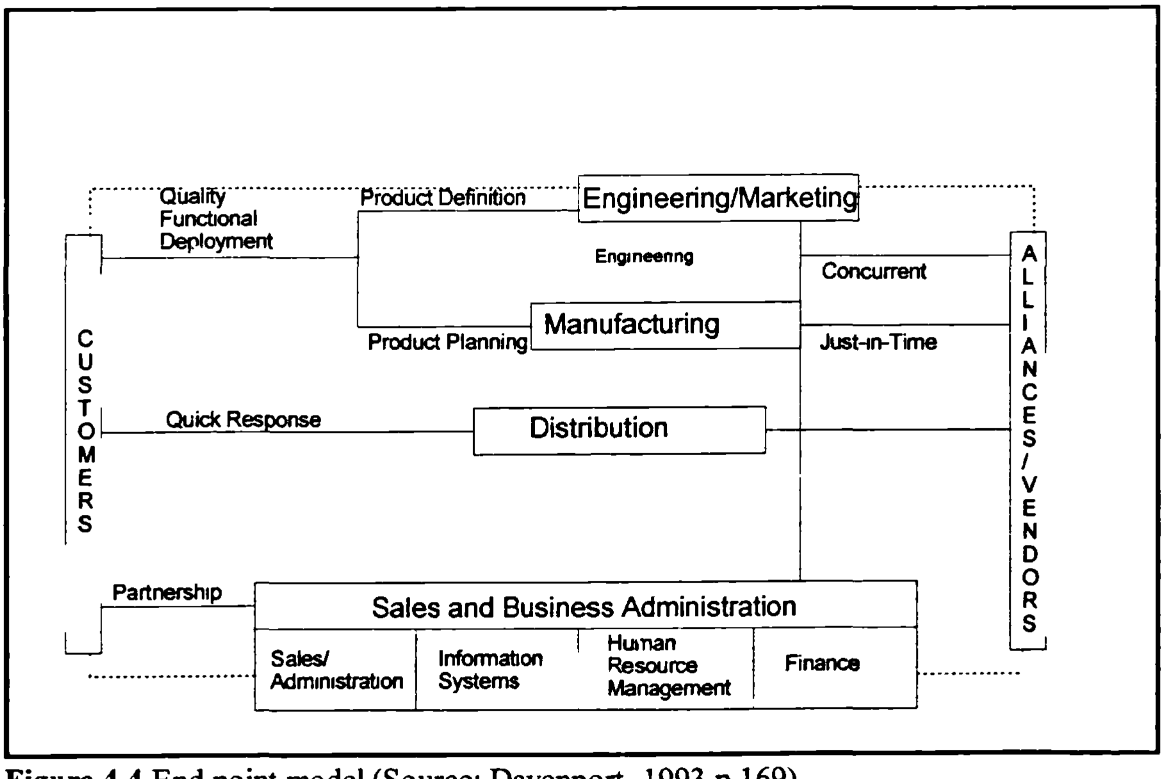


Figure 4.4 End point model (Source: Davenport, 1993 p.169)

A nine month planning period examined competitors and future customer requirements that emphasised the importance of reducing manufacturing cycle time in order to meet customer demands for responsiveness. Reducing the time from vendor shipment of parts to delivery of products to the customer required a major linking of the numerous suppliers and DSM groups who were geographically dispersed.

The five year plan, shown in figure 4.5, was "IT and culturally intense". Computer Aided Design (CAD), Computer Integrated Manufacture (CIM), Artificial Intelligence (AI), group technologies, and other sophisticated manufacturing systems were required to achieve the plans objectives. These in themselves created new work structures for the many people affected. A section of the plan which considered the logistics functions called for a reduction of product-delivery cycle time from 40 weeks to 15 days over the five year period. Complex measuring parameters including materials and resource planning (MRP II) techniques were introduced to measure progress.

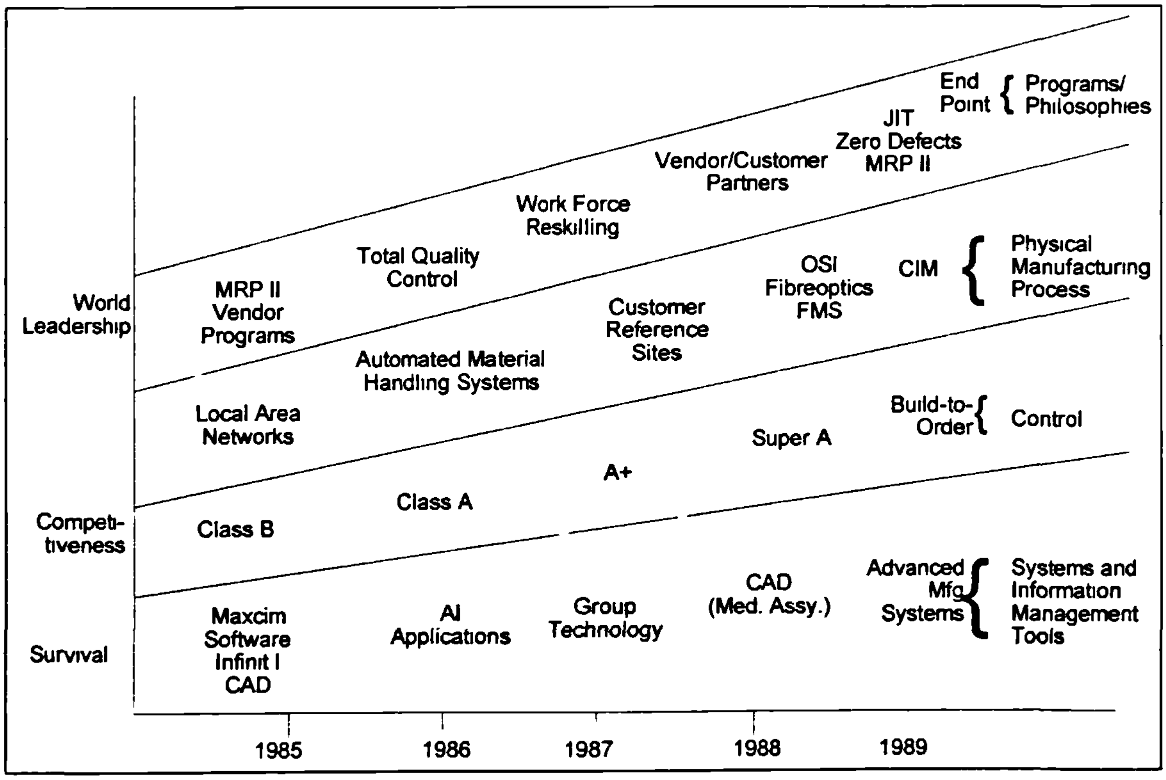


Figure 4.5 The five year plan. (Source: Davenport, 1993, p.170)

At the time Digital were a successful group and so generating the motivation for change was critical. The DSM manager had been preparing for the difficulties which such change required prior to his appointment as head of DSM. He had carried out much background work on developing a new approach to a manufacturing company which focused on an integrated enterprise. His first task when appointed was to seek out all performance measurements for the division which demonstrated how poorly it was performing. These comparative statistics were both against other divisions of DEC and against direct competitors. This benchmarking exercise created the impetus for change.

The next stage required a change in attitude from those involved in the DSM operations. A longer term view was introduced which clearly demonstrated the benefits of changing the attitude of 'what is good for the company' to 'what is good for the enterprise'. This required the replacement of strong functional and job focus to a cross-functional , cross-organisational process orientation. Informal systems and poor controls had to be replaced by a disciplined, measures set of formal process tasks. The adoption of such radical elements, which fundamentally affected the workforce through empowerment, team working, shared IT databases, necessitated DSM to invest heavily in training courses and education programmes to support the changes. Above all, the head of the DSM division was absolutely committed to the radical changes and long term plan. This, together with the other senior management's determination was necessary to ensure that the motivation did not waver during the implementation phase.

The DSM's group manager formed an executive team. Here the full representation of all factions was important. Members of the team represented all the major cultural, operational, and geographical elements of the group and also included important customers. The very diversity of the team led to its strengths as it ensured that all ideas endorsed were subjected to a variety of viewpoints which could not have been achieved by any one sub-group. Team members learned to listen to one another and they challenged unspoken assumptions. After nine months the team emerged with a plan, strong group identity, reshaped perspectives and values, new skills and behaviours, a commitment to its vision, and a belief in its ability to work together.

The success of the reengineering programme implemented by DSM between the period 1985-1988 can be seen from figure 4.6. A key point to the success was the declaration of no job losses. A great deal of effort was expended on relocating displaced personnel. Indeed one of the expert systems developed out of this programme was an outplacer/career planning system.

Process		*Financial*	
Cycle Time	-52%	Inventory	-60%
Time to Market	-30%	Revenue	-2x
Quality	+95-99%	ROA	+25 points
Delivery	+85-95%	Margin	+25 points
Product intros.	+2.5x	Headcount	Flat

Figure 4.6 The success of BPR (Source: Davenport, 1993, p. 171)

Although this case study concludes on the expected positive results as shown in figure 4.6 the story does not finish there. In an article in the Financial Times (11.5.94) Digital Equipment Corporation's recent performance was carefully analysed. The report stated that DEC's recent performance had been so poor that there were major concerns about its future. The slump in performance was mainly caused by an inability to compete with low cost competitors producing powerful workstations (Sun Microsystems for example). A change of Managing Director brought a new emphasis on forming more focused work "clusters" which replaced the 140 plus business units which existed in 1992. This point is crucial to the BPR issue. The revitalisation of one aspect of an overall organisation's business operations is still only a partial solution. The success of the DSM group clearly did not, of itself, guarantee DEC's success. Although influential over the DSM group the head of DSM was not representative of the senior DEC management who clearly adopted an entrepreneurial management philosophy for the business units. The lethargy in the DEC corporate management led to poor forecasting and continual erosion of margin and market share. By 1994 the situation was dire. The managing director had to instigate savage cuts to personnel in an attempt to quickly reduce costs. Such a difficult position forces actions to be made on a short term basis which undermine efforts and initiatives which have been gradually built up.

This stresses the importance of vigorously monitoring the competitive environment in which the organisation is located. Failure to do so can lead to abject failure.

4.7 Beyond the theory

The history of Business Process Reengineering has been comparatively short being first recognised in articles produced by Hammer and Champy in 1990. Over the last three years there have been two clear developments which have done much to temper the initial enthusiasm for BPR. The first development was the large scale adoption of BPR as a marketing tool for management consultants and related business professionals. The nebulous nature of BPR allowed a considerable variation in advice with many contrary elements. the use of BPR for reducing the size of organisations through restructuring and 'downsizing' has led to BPR being synonymous with staff reducing reviews. There has also been a concentration on carrying out limited BPR on only part of a company. At the worst extreme this is no more than fine tuning an existing operation without any clear analysis of whether the original way of operating is valid.

A comprehensive study of more than 600 BPR projects in both Europe and North America by the CSC Index (Financial Times 1.7.94) carried out during 1994 confirms this, referring to a 'poverty of ambition'. The study suggests that not only do companies not question their ways of doing business, but they fail to consider whether their corporate and business strategies are still competitive. The study also points out that top and senior managers fail to maintain their initial enthusiasm for reengineering. A key aspect of such radical change as BPR is the enthusiasm and resolve required from the top management level. By delegating responsibility to lower management levels, a company will encourage existing demarcation lines to be maintained.

The final area of concern found by the CSC survey is that there is a lack of cultural change in organisations embarking on BPR. For BPR to be fully successful in what CSC refer to as 'real' reengineering, there has to be a fundamental change in corporate culture for the vast majority of western companies. The use of multi-skilled teams and 'case workers' with cross functional responsibilities and incentive and reward schemes designed to mirror company wide performance and customer satisfaction all necessitate a change from line management systems and hierarchical company structures.

The issues involved with BPR are radical if the full implications of the original concept as originally suggested by Hammer *et al* are fundamental, drawing on issues such as strategy, culture, organisation structure, and long term planning. As noted by various authors, true BPR can yield dramatic improvement but at considerable risk. The area which appears from the reporting in the business press is that many of those actively involved in managing businesses have looked to BPR as a 'quick fix' at a time when world wide recessionary pressures were shrinking markets and capping the tolerable price increases. Many companies have therefore reported BPR endeavours, yet there have been few reported success stories given the apparent widespread participation. The companies who remain cited in both the academic literature and the business press are commonly regarded as being leading edge companies. Some, such as IBM and Digital, have had to cope with enormous commercial pressures, partly brought on by their complacency, yet are capable of radical change to avoid collapse. Other companies such as the American food retailer Wal-mart, run by the late Sam Walton have been challenging standard methods of business for years.

The rapid increase in interest in BPR has generated many diverse sub-areas. Academics, consultants and practitioners have generated vast numbers of articles, books and systems, all designed to offer substantial solutions. The American Society for Quality Control's 48th annual congress held in 1994 addressed the issues of BPR and there were a number of areas covered. From many examples of BPR, drawn from a wide range of businesses, to definitions of specialist areas of BPR, the congress illustrated the booming nature of the subject area. As an example Lowenthal (1994) offered a specific definition for a new term, that of Organizational reengineering:

> 'The rudimentary rethinking and redesign of operating processes and organizational structure, focused on the organization's core competencies to achieve dramatic improvements such as reduced cost, increased product and service quality and increased market share and profitability.'

Interestingly, Lowenthal distinguishes between his term and the accepted definition of BPR..

> 'Organizational reengineering seeks to redefine the way work flows through an organization, which often leads to system and infrastructure changes. Further, this

> process focus the organization on its core competencies (in addition to cultural aspects of change) - a focus that separates organizational reengineering from business process reengineering'. (Lowenthal, 1994)

The role of the manager is defined in this new workplace (Mann, 1994) as well as a number of other pieces of work which assist those operating in the quality field to integrate the ideas of this radical form of quality management into the existing understanding of management.

4.8 Business Network Processes

Two examples of the different ways in which companies adopted a concept which has now been termed *Business Network processes* (Short and Venkatraman 1992) illustrate the potential. In the first, Baxter Healthcare linked with its customers. In the second Wal-Mart obtained advantage through close ties with its wholesale suppliers.

Short and Venkatraman note that by focusing on internal processes, many companies attempts at BPR 'may have little or no measurable impact on the firm's external market performance'. Wal-Mart and Baxter Healthcare illustrate both the success and importance of the inclusion of external parties to the process evaluation. Wal-Mart, the most successful retailing company in America during the early 1990s (Business Age February 1994) developed as an independent retailing chain. The difficulty in establishing close links with suppliers initially led to a central distribution centre which serviced the ever increasing number of stores. As a discount based food supermarket, bulk purchasing of supplies and efficient distribution were key to any success. With bulk repeat items such as soap powder, the cost of transport and off-shelf stock holding was expensive. Wal-Mart therefore eventually convinced certain suppliers to take on responsibility for stock control of their own products within the Wal- Mart chain. Since the volume of trade generated by Wal-Mart was so great, the supplying companies had a vested interest in maintaining good relations. The information necessary to make this feasible was provided by networked in-store computers linked to regional distribution centres and ultimately back to the Wal-Mart headquarters. Such has been the success of this linking of Wal-Mart to its suppliers that several have chosen to locate their administrative centres next to Wal-Mart headquarters.

Baxter Healthcare, a major supplier of medical supplies, installed computer terminals in hospitals for supply ordering and concentrated on offering a wide range of supplies. By making the complex task of ordering and monitoring medical supplies simpler, Baxter enabled hospitals to reduce the number of staff required to fulfil this function. Through the use of sophisticated IT (Analytical Systems Automatic Purchasing) Baxter were able to package, distribute and deliver to individual departments supplies within the same hospital. This attention to providing a service beyond that traditionally expected, allowed Baxter Healthcare to expand without concentrating on price competition. In the UK Marks and Spencer have always maintained a close relationship with their clothing manufacturers. M&S management go to great lengths to ensure that suppliers continually meet their exacting standards and price requirements, often on a sole supply contract. In return suppliers are given long contracts and are assured of turnover. Increasingly companies in manufacturing are linking to enable improvements in operations. This is partly driven by the widespread publicity of the Japanese business policy of companies forming symbiotic relationships which are long term based. The increasing dependence on supplier expertise, together with the modern movement towards smaller, highly specialised expert suppliers has meant that companies are employing the skills of outside agencies in strategically important areas. This movement is evident even within large organisations where specialist departments are separated as cost centres who sell their services on the internal market. The National Health Service's adoption of internal market strategies demonstrates how far this philosophy has permeated into a traditional culture.

4.9 The Application of BPR to Projects

There has been little reported research on the application of BPR to project based industries. Where such work has taken place it has focused on the steady state activities, not the projects themselves. This gap in the literature is largely explained by the dramatic increase in resource effort and cost involved in understanding how to apply the tenet of BPR to 'one off processes'. As there is still much to be considered in understanding the consequences of BPR in steady state environments, it is to be expected that there will be a considerable time lag before the approach filters through to the complex world of projects. The Gap Analysis model offers a framework in which to consider such an approach. By examining what occurs in each of the stages and then, crucially, the best way of managing the gaps between the stages, the possibility exists of developing the complete project management system capable of delivering total success.

4.10 Conclusions

For Business Process/Network Reengineering to achieve any long term credibility there is a need for a great deal more research to establish exactly what it is and what it is not. The general media coverage of BPR is simplifying it to the point where any company can believe that it is a painless exercise guaranteed of success. The real implications of fundamental cultural changes, employment opportunities, and length of time for implementation have not been emphasised. If not treated with more caution, companies my find that the only long term effects of BPR will be yet more management consultant fees and another ineffective IT system.

4.11 The Next Stage

The literature and reporting of Business Process Reengineering has concentrated on steady state situations where organisations face repetitive operations. The potential of applying the principles of BPR to project based operations, where risk and uncertainty are higher has, as previously stated, not been fully explored. The emphasis for project based operations is on applying general project management principles to unique situations. Often these projects bring together a group of people, forming a network, with a range of differing backgrounds. Where more than one company is involved, as with construction projects, the complexitv of the management tasks increases dramatically. The traditional response to such increases in this complexity has been to fragment the management functions and create a large number of specialists with specific responsibilities which can be categorised under the headings of technical, managerial, administrative, or financial.

The culture of project based management will be a significant factor in the implementation of Business Process Reengineering Schien (1994) lists nine assumptions that an organisational culture should possess before innovation (BPR) can be implemented. These are:

1. The world can change and change can be managed.
2. Humans are by nature proactive problem solvers.

3. Truth can be pragmatically discovered.
4. The most propitious time horizon is the near future.
5. Time units should be geared to the kind of innovation being considered.
6. Human nature is neutral or good and is, in either case, perfectible.
7. Human relationships are based on individualism and the valuing of diversity.
8. Decision making is collegial or participative.
9. Diverse subcultures are an asset to be encouraged, but subcultures must be connected to the parent culture.

Schien also makes the important link between culture, information technology, and innovation. For complex and dynamic environments such as construction projects, the possibility of implementing more process orientated approaches will require sophisticated IT.

Arleth (1993) considers the characteristics of innovation management compared with operational management. Study of his comparison, given in figure 4.7, suggests that many of his characteristics for *innovation management* are similar to those involved with the ideals of project management.

Task	Innovation	Daily Operations
Output	Intellectual; ideas and methods for production and selling of products (future profits)	Physical; goods in planned quality and quantity (daily profits)
System for production	Networks of people. Social system	Logical system. Machines. Systems for distribution, administration and payments
Nature of activities involved	Cannot be described and planned in advance	Can be described and planned by using known planning techniques
Human abilities needed	Creativity, knowledge, commitment	Discipline - understand orders - follow a system
Organisation of work	Whole tasks	Some are thinkers, others are doers
Planning and coordination	Setting up vision and objectives	Planning of activities e.g. using gantt, PERT, PC or similar
Management principle	Objectives	Operational management

Figure 4.7 Comparison of steady state verses innovation, Arleth (1993), p. 124

The next stage in the research, presented in the next chapter, is the exploration of the issues involved in managing the early activities on a complex construction project. The case study, that of the Glaxo Campus project, considers the full range of issues on this prestigious project, from the project's establishment through to commissioning. The case study forms a valuable insight into the complexity and diversity required in modern construction project management.

Chapter Five
Pilot Case Study
Glaxo Campus Project

5.1 Project Background

The project considered was the construction of a new Research and Development headquarters for Glaxo Group Research (GGR), a subsidiary of Glaxo PLC, one of the top three pharmaceutical companies in the world. The completed project works in conjunction with GGR's sister R&D facility in North Carolina USA. The 30ha site is located adjacent to the A1(M) outside Stevenage approximately 30 miles from London. The project consisted of six large interconnected buildings; a Microbiology Pilot Plant, Chemistry Laboratories, Biology Laboratories/Central Research Support Facilities, Microbiology Laboratories, Administration Building and Central Plant. The green field site provides 130,000m^2 of specialist work environments for approximately 1500 research scientists and 500 support staff. The buildings were designed for specific areas of pharmaceutical research. Emphasis has been placed on providing established technologies in well planned spaces enabling research to be carried out with the minimum amount of inconvenience. An important element of the project was the concentration on external landscaping and the provision of large, airy circulation spaces. The design has incorporated naturally well lit covered walkways and the provision of 'Nodes' which are spacious areas designed for relaxation. This was seen by GGR as a necessity rather than a luxury for, not only does such an attractive environment help to attract the best personnel but, by providing areas where different departmental personnel can congregate together, the potential for the development of new ideas, a key objective of the new complex, becomes greater.

The mechanical and electrical services included in the project account for approximately 60% of the total construction costs with the heat, light, and power for the completed buildings coming from national supplies with the back-up of standby generators. In the most complex areas of the Chemistry building interstitial floors, many nearing full height, carry the services and allow maintenance to be carried out without disruption to the research activities below. Although different criteria can be used to measure the value of the project, a reasonable value for construction and design incurred expenses would yield a figure of approximately £550 million (1995 prices). This made the Glaxo project the largest non civil engineering project in the UK and was second only to the Channel Tunnel Figure 5.1 gives an aerial view of the project midway through construction

Figure 5.1 Aerial photograph of the Glaxo project during construction, Laing Management Ltd

The GGR Research and Development project has been under consideration since the early 1980s. The final scheme commenced during 1988 and followed an aborted first attempt located on the same site. The original scheme, which was under consideration for approximately five years, was intended to provide similar facilities to the present project but was organised in a fundamentally different way. Whereas the final project utilised personnel, expertise, and methods drawn from around the world and several industries, the original project employed UK players and UK construction systems The potential for poor performance of the first project, together with its timing during the 'boom' phase of a particularly severe building cost cycle led to dramatic action, and eventually to a totally revised project

The series of buildings proposed in the revised scheme had a smaller footprint than the first project considered, but provides enhanced facilities in a more pleasant environment and has far less uncertainty about the out-turn cost.

The contractual relationships involved on the first project are given in figure 5.2a. This can be directly compared with figure 5.2b which shows the revised relationships.

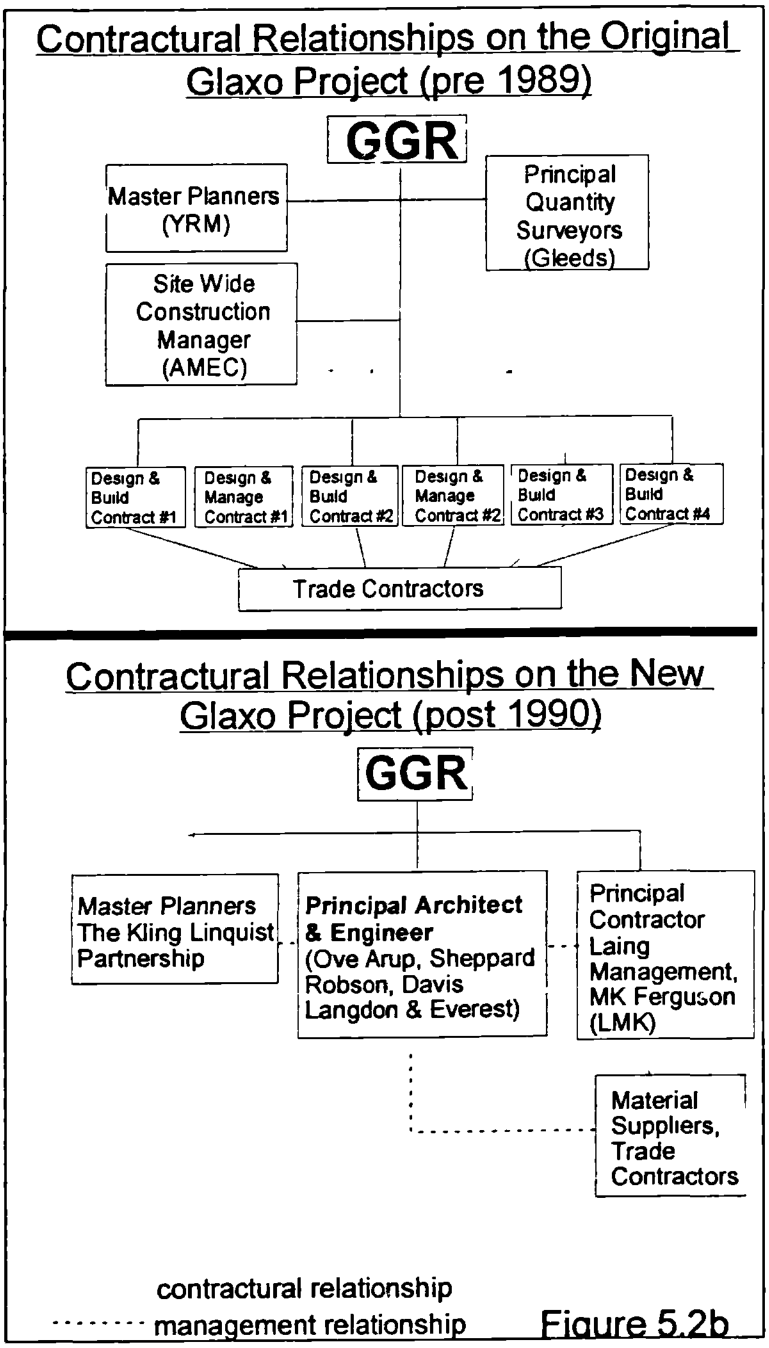


Figure 5.2a & b Contractual relationships at Glaxo (Source LMK)

Starting at the bottom of the diagram 5.2a, each individual building was let on a Design and Build or Design and Manage contract. As each building represented a large contract, in construction terms, the contracts were awarded to major UK construction companies including Trafalgar House, Laing, Taylor Woodrow, Henry Boot, and Davy McKee, each of whom employed the services of some of the largest UK design practices and used major construction contractors. A construction manager (AMEC) was placed in overall control of all of these contracts and ensured coordination and uniformity. Providing project cost control was the Project Quantity Surveyor (Gleeds) who reported to GGR. The master planner for the original scheme was YRM.

As the various building contracts were awarded and more detailed design work commenced, it became clear to the PQS (Gleeds) and hence GGR that the overall costs were beginning to escalate beyond the intended budget. GGR became increasingly concerned about the cost control elements of the contracts and sought to control the escalating costs.

The timing of the commencement of significant expenditure was an added problem, as the construction industry at that time was rapidly approaching the peak of a particularly strong building cycle and was showing clear signs of 'overheating'. The first casualty of the poor economic circumstances was the proposed headquarters building which was provisionally valued at £50 million but which was being subjected to construction cost inflation approaching 18% p.a. Glaxo's public cancellation of this element of the project in June 1989 was referenced in the press as being indicative of the mood in the development world and was expected to be followed by other developers on other projects.

The main Glaxo board decided to appoint new individuals to control the project. The new team was headed by Michael Herriot, an Englishman who had successfully completed GGR's US research facility at Research Triangle Park in North Carolina. This new US facility is smaller and less complex than the UK project, but successfully addressed many of the issues which needed resolution in the UK.

The new project manager was given authority to take whatever actions were necessary to bring the project back into line with the intended budget. From the outset it became clear that the scale of the problem was beyond the capabilities of one individual. GGR continued to place experienced personnel, many well versed in petro-chemical project management and complex pharmaceutical plant construction, on the project as necessary. There was an increasing realisation that major changes were needed. The new project management team from GGR established a hierarchical organisation structure which remained throughout the later stages, as shown in figure 5.3.

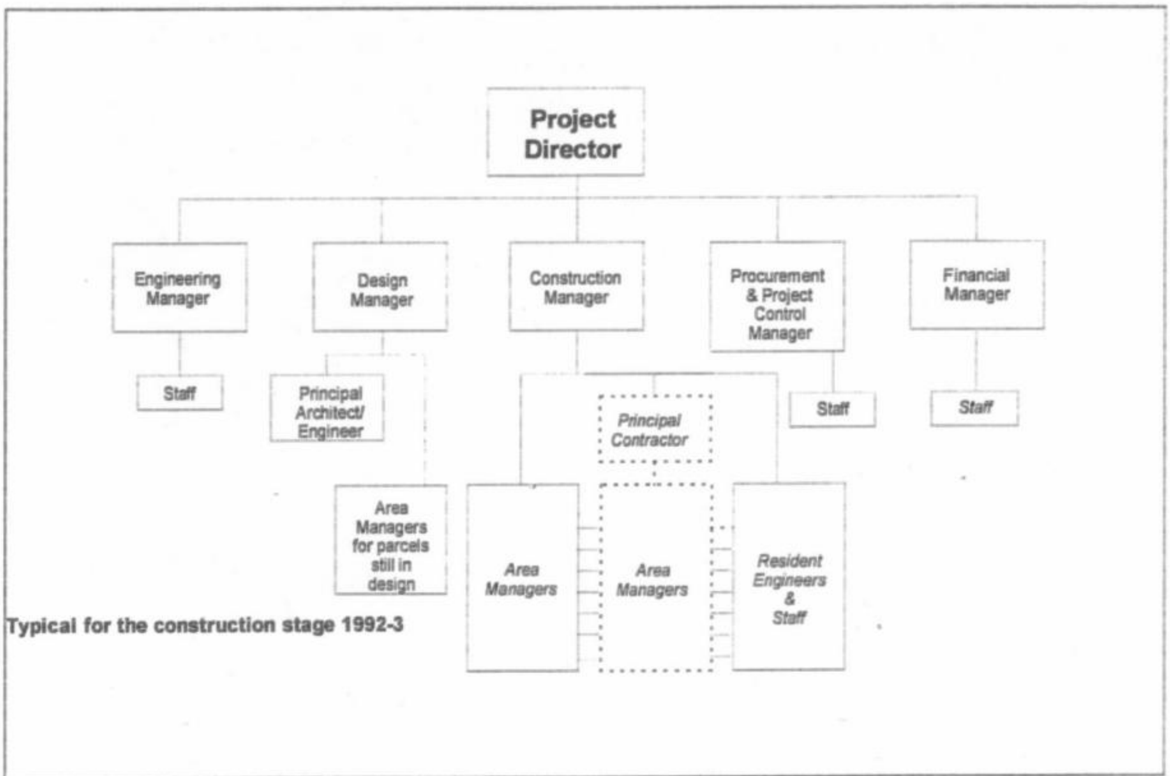


Figure 5.3 Internal organisation of GGR (Source, GGR, LMK)

The new GGR management formed an audit team using outside consultants, including design practices, to thoroughly investigate the situation on the project. The result of the audit was for a recommendation that the majority of contracts be determined as there was no way to control the escalating costs, given the number and types of contract being used. At that stage, early 1990, site wide enabling works had begun and many of the D&B contracts were well into the design stage. Of the individual D&B contracts which had been let, the first was for a Chemistry Pilot Plant which had been awarded to Trafalgar House. GGR decided to continue with this building only, as the construction phase had started. All other contracts including that of AMEC and Gleeds were eventually determined.

5.2 The New Brief

The new Glaxo project lifecycle is illustrated in figure 5.4. GGR needed to maintain the momentum of the project as it was vital to their worldwide operations. The head of their new

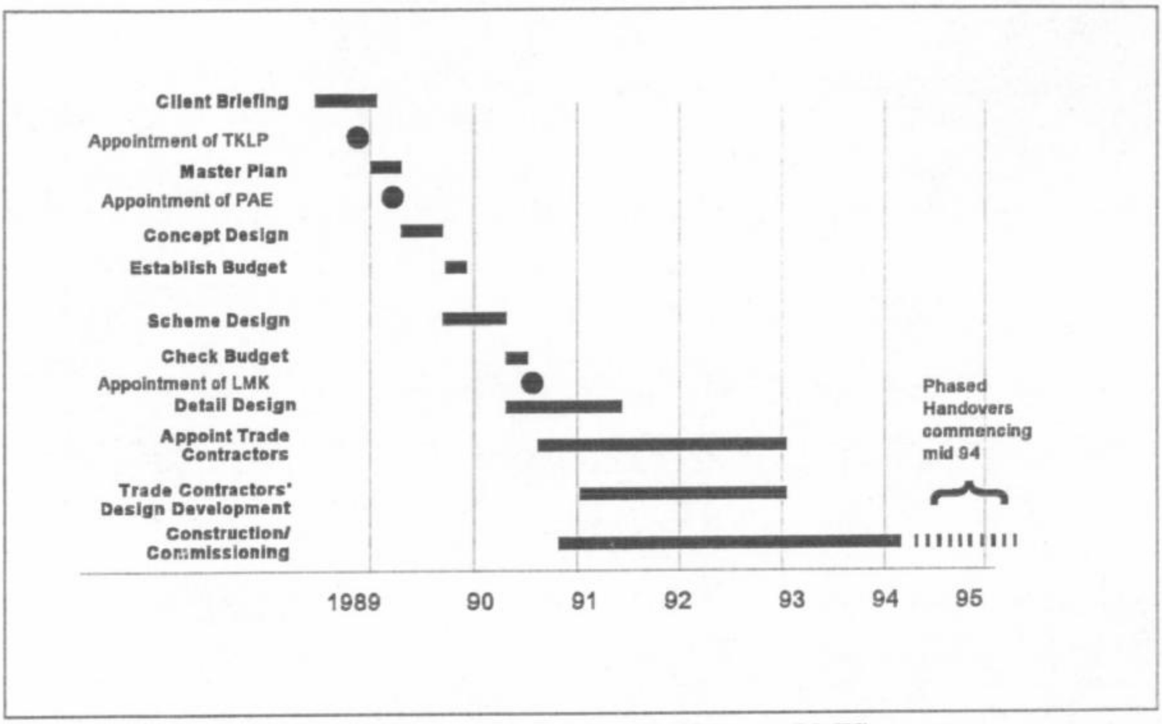


Figure 5.4 Timescale for the Glaxo project lifecycle (Source, LMK)

project team was therefore required to provide a replacement project plan straight away. Having carried out a thorough review of the original scheme and familiarising themselves with the scale of the problems faced on the original project, the new project management team had to resolve a number of key issues before launching into a revised scheme. The first area of concern was the goals to be achieved through the building of new research facilities.

As a premier research organisation, Glaxo had to provide suitable facilities for scientific research to take place. This meant understanding the needs of the research scientists and translating these into a realisable project. This process of liaising with the users was crucial to both the design and construction process, as well as to the ultimate usefulness of the completed building(s). The GGR management imposed strict guidelines for this stage with all end users' departments given agreed budgets which were to be used to provide their required facilities. If any department wished to exceed that budget then a case had to be made which, if large enough, would need Glaxo main board approval. By imposing such strict rules, GGR were able to substantially control the problematical stage of identifying user requirements and locking that into the design process.

It became evident that the original scheme had some failings in providing a suitable environment in which varying forms of research would take place. For instance, the concept for the design was altered to focus on providing areas of the complex known as 'nodes' where scientists could congregate. By re-examining the objectives of the project, key changes continued to be made. Glaxo's objectives for the new project were widened to include the actual process of construction. Glaxo as a player in the highly regulated industry of drug development and manufacture sought to apply stringent controls to the construction of its new R&D campus including the establishment of a rigorous safe method of working. Glaxo's summary objectives for the new project were:

Scientific objectives

- To remove technical restrictions where possible whilst accommodating all statutory requirements
- To consolidate UK research on one site

Design and construction objectives

- To be the safest construction site in the UK
- To have considerable influence over the design and construction
- To have certainty of outcome on cost and programme

With these new clearly defined objectives the new GGR project team immediately secured the services of a company who would be able to develop a brief and master plan.

5.3 The Design Players

a. The Master Planners

At that stage (late 1989) The Kling Lindquist Partnership (TKLP) from Philadelphia, USA were brought in as master planners and concept designers as well as to assist in the early data gathering exercise, as they had provided a similar service on the Research Triangle Park project. Glaxo and TKLP worked for four months in the US analysing the needs of the users and forming initial ideas. By the end of this period Glaxo had reduced the scope and cost of the second project compared with the first, whilst improving the potential of the scheme. This understanding led to a more compact campus design, with the emphasis on aesthetics and ease of movement. The exercise of returning to examine the fundamental objectives and establishing a set of criteria that the client could concisely express and enforce for the project, set the context for the remaining stages of the project.

The Glaxo project managers decided to approach the problem of how to handle a project of this size and complexity in a completely different way from that originally chosen. The original project was seen as being too big to be handled by individual design and construction companies. The solution was to divide the project into a series of discreet projects which could be allocated to individual companies. The contractual route chosen for the first project was Design and Build or Design and Manage with additional global management and cost control. The new approach, based upon a clearer understanding of what was required, was not to subdivide the project but to combine individual companies expertise into consortia capable of undertaking a project of this magnitude.

Although using US Master Planners, the Glaxo project management wanted to deal only with UK based consultant companies as the problems of logistics and communications involved with using international consultants would have been untenable. Therefore. at the beginning of the four month period, when The Kling Lindquist Partnership commenced the master planning stage in the US, the GGR project team was preparing to appoint a UK based design team to continue design development.

b. The Principal Architect and Engineer

When considering possible parties for the designers, GGR wanted to deal with only one company. As the technical and administrative demands of the proposed project were considerable, there was no one UK based company capable of satisfying all of Glaxo's demands. The contenders for the consultants role therefore comprised consortia which were required by GGR to form a new joint venture company specifically for the project. GGR insisted that cost control expertise was part of the design and so a quantity surveying practice was to be part of the consortia bid. The form of contract chosen by GGR for the appointment of the PAE was a fully reimbursable fee. Clearly such a form of contract puts great emphasis on the management structures at GGR, as staffing costs could easily escalate. This potential problem was considered and emphasis was given during the selection period to the control and approval of staffing levels by the client. The staffing and organisation of an integrated design team were key aspects of the selection procedure as well as being orientated towards providing the quality of service and deliverables and the personalities and style of the management proposed.

Once selected the successful company, known as the Principal Architect and Engineer and comprising Ove Arup and Partners (structural, mechanical, and electrical engineers), Sheppard Robson (architects) and Davis, Langdon & Everest (cost consultants), was appointed early in 1990 (four months after the appointment of TKLP) and began the development of the design through its various stages. Ove Arup had been part of the audit team used by GGR to assess the first project and Sheppard Robson had been involved in some design work and so brought with them an element of understanding to the project's design parameters. As the master planning had been carried out by the TKLP, the PAE required as much involvement as possible in the early stages of design so that the PAE's risk of compromising the design's intent would be limited An initial PAE team of 12 (three mechanical engineers, one piping engineer, one electrical engineer, one structural engineer, one quantity surveyor and five architects, each responsible for a building) liaised with TKLP in the US and was involved in the continuing client review meetings. This initial dialogue was important for the PAE as TKLP had only begun data gathering one month before the PAE team's arrival. Apart from assisting the TKLP at this stage the PAE's responsibilities were clearly defined. They included:

- Participating in the development of the Master Plan, with particular emphasis on those aspects of the design where the knowledge of statutory, local authority, and UK Building Regulations was required.

- Providing assistance to TKLP in the development of alternatives for the engineering and architectural systems.

- Assisting TKLP in preparing documentation prior to submittal for planning approval.

- Undertaking soil surveys in collaboration with TKLP.

- Participating in the Environmental Impact Assessment.

GGR actively sought to bring in all the key parties at the earliest stage and thereby create significant overlaps between stages. Hence the PAE was brought in during the master planning stage when TKLP had only been working themselves for a short period. This policy was extended to include the appointment of the Principal Contractor who, unlike AMEC in the previous project set-up, was intended to contractually control all construction operations. This strategy of overlap is illustrated in figure 5.5.

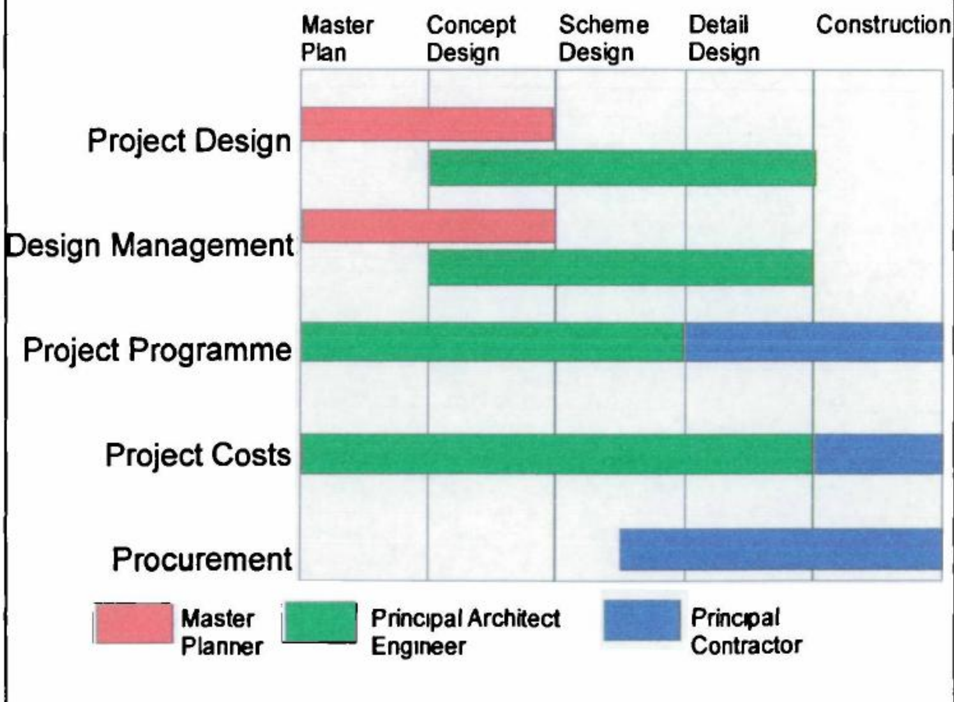


Figure 5.5 The overlap of responsibilities Source: PAE

GGR had kept the momentum of the project moving forward sufficiently in the public arena to enable all the major UK contractors to be aware that such an appointment was likely to occur and many were preparing for the expected submission procedure.

c. The Principal Contractor

GGR involved the PAE in this preparation process and sent out comprehensive information to those of the largest UK contractors capable of handling such a project. An exhaustive selection procedure commenced which required formal submission of proposals from prospective firms, curriculum vitae for key personnel, and an outline for the management of such a project. The contractors were bidding on a fee plus reimbursement basis on a contract based on the Joint Contracts Tribunal (JCT) Construction Management form of contract but which had been extensively adapted by GGR's legal representatives to include many additional cost control elements and provide GGR with access to a 'transparent' series of subcontracts. GGR desired to have a management contractor who procured all subcontracts and administered them but wished to have access at all times to these contractual relationships to ensure that significant problems were not masked from them.

The final selection was reduced to a choice between Bovis and Laing Management, both of which had formed joint ventures with specialist US construction management companies because of GGR's tendency to follow US construction methods of management. As Bovis had extensive knowledge of working in the US, it was felt by those in the industry press that they would be most likely to win the contract. However GGR required both finalists to attend meetings at which each would present key personnel and discuss the project. Bovis chose to concentrate on their previous experiences and reassure GGR of their impressive track record and maintained a distinction between themselves and their joint venture partners. Laing, in contrast, chose to adopt a more technical theme and present initial engineering solutions to what they perceived as the key construction problems. In addition Laing deliberately mixed their team with the members of MK Ferguson (a division of the US company Morrison Knudson) who were their joint venture partners. This approach suited the project culture which GGR had fostered and, although many other criteria needed satisfying, helped Laing and MK Fergusson (known as LMK) to win the project.

The Principal Contractor's responsibilities were to plan, coordinate, and manage the execution of the construction stage. In order to achieve this, key engineering design staff were involved with both TKLP and the PAE from the outset. Construction concerns were considered at this early stage and sequencing was also an important consideration. GGR wanted all the construction subcontractors to be procured on a fixed fee lump sum basis so that budgets could be locked in, and not lead to the cost escalations previously encountered.

The most senior level of project management for the Glaxo project was a three person triumvirate as shown in figure 5.6. The concerned parties of GGR, PAE and LMK were each represented by the most senior full time individual concerned with the project, who formed the executive level of management. Figure 5.6 also summarises the organisational structures of the three organisations.

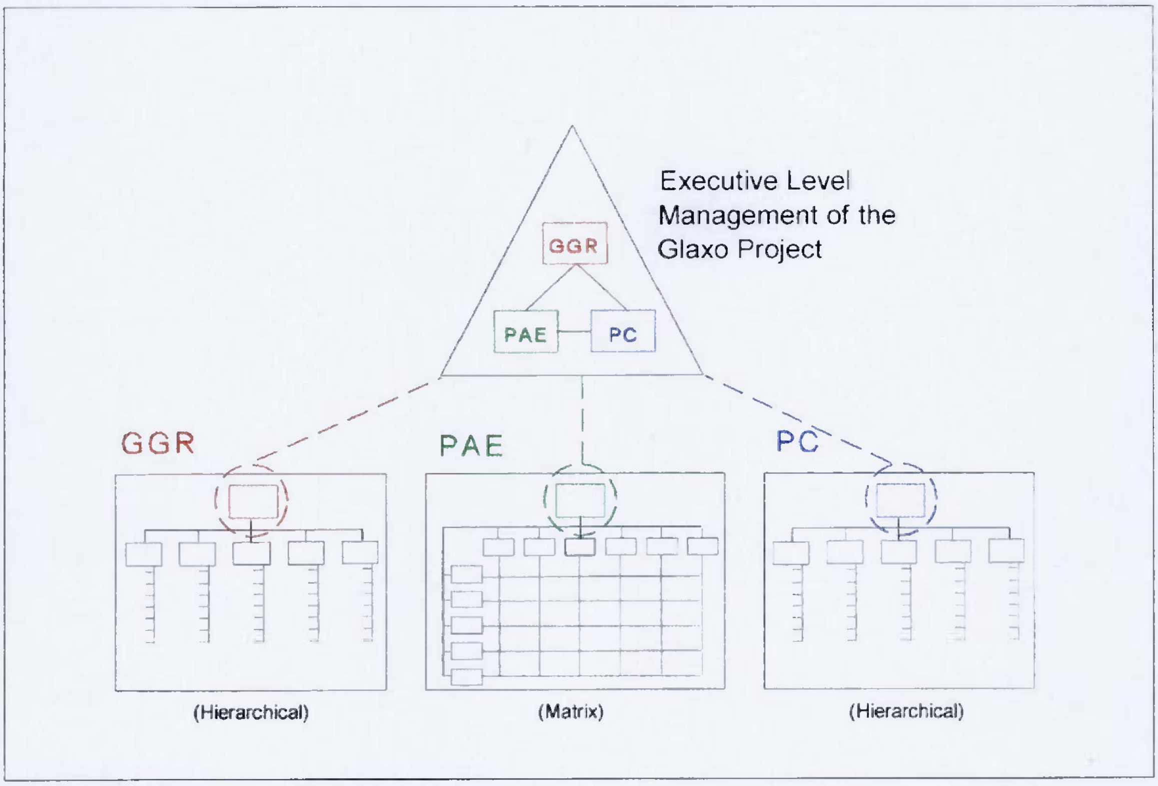


Figure 5.6 Management structures on the Glaxo project

5.4 The Design Process

An important aspect of the way the revised Glaxo project has been organised is the way in which the distinct stages of a traditional construction project have been overlapped. Although, for ease of exposition, the traditional titles, as described by the RIBA Plan of Works were used, there was a deliberate policy operated by GGR to bring on board at the earliest opportunity, players whose main role would lie further downstream. Thus very shortly after the appointment of the TKLP the PAE were selected and representatives sent to the US to assist in Master Planning activities. Later, the Principal Contractor was brought in during the peak of the PAE design period so as to provide additional advice and participate in Value Engineering exercises. Finally, the trade contractors were procured before the design was fully resolved so that they were able to provide the most practicable details to complete the design in accordance with the designers intent. Although the overlapping of players creates a more continuous flow of information than normal, the different phases of the Glaxo project can be categorised according to the outputs from each stage. Figure 5. 7 lists the outputs of each phase.

Master plan	Concept Design	Scheme Design	Detail Design
Master Plan Layout 1:750	Building layout Drawings (1:200)	Architectural & Engineering Reports	General Arrangement Drawings (1:50)
Brief	Engineering System Scheme	Building Layout Drawings (1:100)	Design Details
Building Block Layouts (1:200)	Basis of Design	Engineering General Arrangements	Technical Specifications
Master Plan Estimate	Statement of Criteria	Equipment Data Sheets	Pre-bid Estimate
Project Master Programme	Concept Design Estimate (+/-15%)	Scheme Design Estimate	
	Basis of Estimate	Basis of Estimate	

Figure 5.7 Design phase outputs (Source, Ove Arup)

5.5 Master Plan and Concept Design

TKLP were responsible for carrying out the required interviews and meetings to collect the relevant data. The objective was to establish the building users' specific objectives together with meeting the owner's requirements for the project. In addition to the TKLP, there was an early involvement from a highly pro-active owners team. TKLP spent approximately six months during the first half of 1990 developing the client's brief. The final document comprised client review notes, user interview records, and a range of technical information. During the latter stages of master planning and throughout concept design, the PAE became actively involved in the preparation of a set of documents which were issued by the TKLP and were known as the Control Documents. The master planning and concept design stages together took 15 months to complete.

The Control Documents articulated the client's requirements to the master planners. They were the basis for all future design work carried out during scheme design and detail design. The documents drew upon four sources of data: GGR's own experiences, TKLP's related experiences, interviews with operational and user groups, and relevant UK Codes and National Standards as provided by PAE representatives. The Control Documents were individually tailored to the specific requirements of each building.

A typical control document contains both qualitative and quantitative data for the individual spaces to be accommodated within the structure. Detailed analysis of information was carried out by each discipline, such as architectural, structural, HVAC, electrical, lighting, plumbing. and fire protection. Control Documents also contain technical information, recommendations of the type of system to be used, relevant sketch drawings to explain a system, and a cost estimate for the concept design stage. The Control Documents themselves can be divided into two sections.

i) Statement of Criteria (SOC)

This listed criteria for specific buildings as well as standards which were applicable to all buildings on the campus. This document was prepared in conjunction with Glaxo, using their previous experience, particularly the recent construction of their North Carolina facility, to ensure that the client would obtain satisfactory solutions. Throughout master planning and concept design a number of formal reviews were held with the client so that the document could be validated as an official representation of need.

The SOC was the document which summarised all the relevant data and information that TKLP had collected from all sources. It systematically listed the relevant information after considering the client's requirements. It also gave a clear picture of what the individual building design teams need to aim for, in terms of standards and equipment.

ii) Basis of Design (BOD)

The SOC was used as a base for developing the second section of the Control Documents known as Basis of Design. The design criteria from the SOC documents were used to recommend technical systems which were to be used in the various buildings. For example, heating loads were calculated in the SOC document whereas heating systems were suggested in the BOD document. The BOD therefore provided a detailed outline design document which identified those specifications which were considered vital by the client for the project's overall success.

TKLP and GGR had explicitly written in to the various contracts that there would be clear handover points in the design and that these would be subject to formal inspection by GGR. These break points allowed GGR to review the design both technically and financially and were used to ensure that the project was not deviating from those target values intended by GGR.

5.6 Scheme and Detail Design

At this stage, more detailed building layout drawings were produced in addition to the preparation of documents such as architectural and engineering reports, engineering general arrangements, equipment data sheets, and scheme design estimates. These were then referenced back to the Basis Of Estimate which formed the financial element of the Control Documents. Full cost estimating also began during this stage. Once the initial design was completed in the US the work was transferred to the UK. Here the vast majority of the remaining design was to be carried on. The total design drawings produced by the PAE (except for team #4) are given in figure 5.8.

Glaxo Project Design Drawings

	TEAM #1 Microbiology 36,500m2	TEAM #2 Biology/CRSF 28 400m2	TEAM #3 Chemistry 37 100m2	TEAM #5 Admin/site 10 800m2	TEAM #6 Central plant n.a	TOTAL DRAWINGS
Architecture	263	390	330	248	111	**1,287**
Strucrture	186	296	244	154	157	**999**
HVAC	107	126	150	85	55	**501**
Piped services	170	121	145	n.a.	38	**440**
Electrical	174	250	205	149	81	**824**
Total	**716**	**1,183**	**1,074**	**636**	**442**	**4,051**

Figure 5.8 Design deliverables for Glaxo

A project design office was established at Howland House, one of Ove Arup's London buildings and housed the whole project design team and the GGR project staff. The Glaxo project's design was organised by GGR by dictating the structure of the design team so that the traditional structural predominance of the design stage was replaced by a more process orientated organisation. The co-location of the various design experts in one building, minimising communication problems and maximising knowledge sharing was a key factor in reducing the number of problems encountered during this complex stage. The investment by GGR in providing sophisticated networked CAD and IT was to enable the designers to concentrate on resolving the technical design matters and not co-ordinating the design.

By creating an attachment to a particular building in preference to a segregation along professional lines, GGR sought to avoid the 'stovepipe' mentality where different elements of the design are completed in relative isolation, often with conflicts or omissions. The teams established worked from early scheme design through to the final detail design and so were more process orientated than the stage model often adopted. The detail of the organisation of the PAE is shown in figure 5.9.

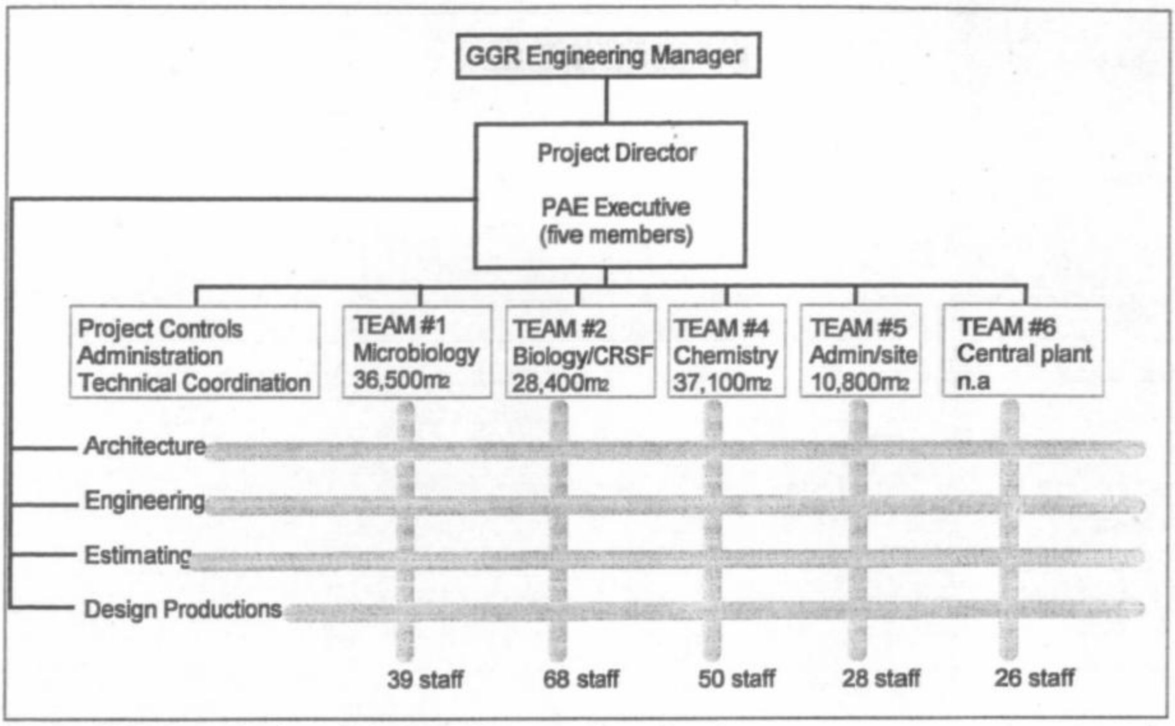


Figure 5.9 Organisation of the PAE (Source, Ove Arup)

This diagram shows that the PAE project design was headed by the PAE executive which consisted of the Project Director and five directors, drawn from the three participating firms. Reporting to the executive were five project managers, each responsible for the team which concentrated on the design of a specific building or facility as listed horizontally. Each of the PAE project executive were responsible for one aspect of the design as listed along the vertical axis.

The design work itself was carried out by the design teams which were multi-disciplinary in nature. These project teams were supported by the Project Control Group which included a Project Controller, an Administrator assisted by a Document Controller, and a Technical Coordinator assisted by a Drawing Controller. These coordination and control services were provided for the whole project by this central group in order to achieve consistency of approach. A separate manager was responsible for Design Production and coordinated the production and storage of drawings prepared by each team. As with any dynamic situation the detailed structure within each project team was subject to change throughout its lifetime, however, a typical project team organisation is given in figure 5.10.

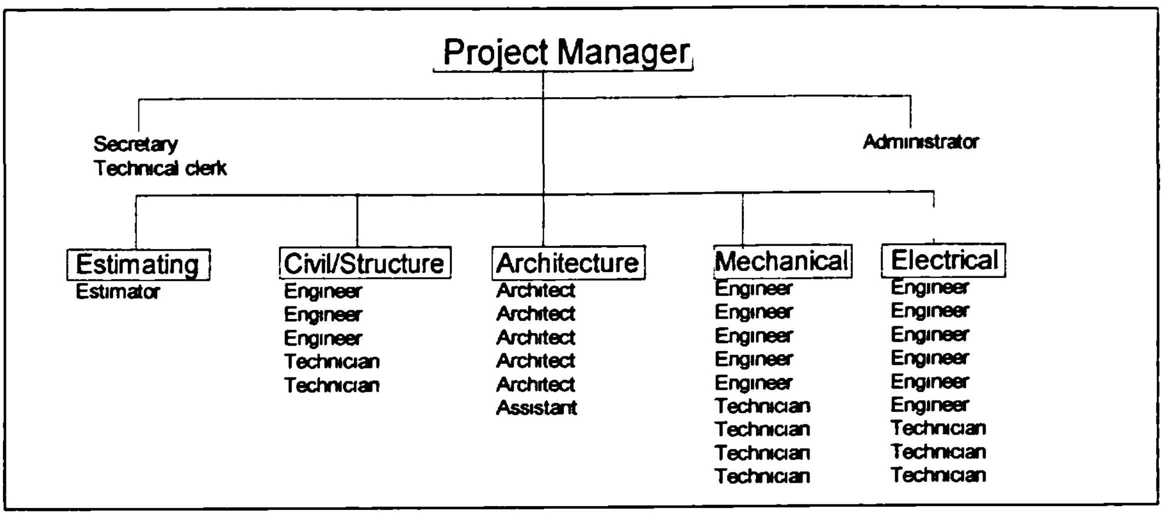


Figure 5.10 Typical Building design team (Central Plant building), (Source, Ove Arup)

Each team was run by an individual project manager supported by a Team Administrator. The Team Administrator acted as a design team manager and was responsible for monitoring the programme, resources and design costs on a day to day basis. The Project Managers and Administrators were selected from all three firms which comprise the PAE. Each team was centred around professionals working in the disciplines of architecture, civil/structural engineering, mechanical engineering, electrical engineering, and cost estimating.

The co-location of integrated teams was meant to ensure that each team liaised with the other design teams. A group of professionals from each discipline met across teams to ensure that there was consistency of standards. In addition to those professionals from each Design Team, representatives from the Project Control Group also participated in those liaison meetings. These horizontal coordination meetings were held every two weeks. The purpose was to monitor standards across all the teams, coordinate individual progress and raise matters of concern for discussion. Such frequent horizontal contact was important when all the teams were progressing concurrently.

In addition to the individual building design teams there was a Central Design Team which dealt with the planning and standardisation of site wide elements such as cladding, toilet layouts, staircases, and external works. The Central Design Team ensured that key site wide elements were standard and provided common design solutions rather than each team having to 'reinvent the wheel'.

A formal Scheme Design Estimate was carried out when engineering design was between 30-35% complete. This estimate was used for appropriating funds and to provide the cost control budget for the project.

5.7 Design quality control and quality assurance

The PAE had to operate within a quality framework established by Claxo as part of their company policy. On large projects such as the Glaxo project it had become established that comprehensive documentation was produced to demonstrate the quality procedures which would apply. The importance of those documents had increased as more construction companies were actively seeking to become accredited with BS 5750 Quality Assurance certification. Ove Arup had stated that they believed that the nature of their work did not suit the administrative procedures specified at the time by third party accreditation agencies. They had therefore continued to employ the same principles in their quality assurance system which they had used during the company's 40 year history. This system allowed the flexibility necessary to cover a range of activities, from conceptual design, to technical specification calculations. As Ove Arup had achieved a reputation as a 'quality' design company with a world wide reputation it was not surprising that their attitude to quality was the basis for the quality document used for the design stage on the Glaxo project. The document titled 'The Project Procedures Manual' emphasised the quality of the personnel who were appointed to the positions of responsibility and who would ensure, through their professional backgrounds and additional training, that all the necessary steps had been taken so that all design work is of a minimum satisfactory standard. Within the Project procedures manual the Project Quality plan (PQP) distinguished between quality assurance and quality control.

Quality assurance is defined within the manual as

> '...a programme or plan covering activities necessary to provide quality in the work to meet the project's requirements.
>
> Quality assurance involves establishing project-related policies, procedures, standards, guidelines, and systems necessary to produce quality'.

Similarly quality control is defined as

'...the specific implementation of the quality assurance program or plan and includes checking and reviewing design related activities.'

'Effective quality control reduces the possibility of errors, and omissions.' (Source GGR)

The PAE's organisational structure for ensuring quality is given in figure 5.11.

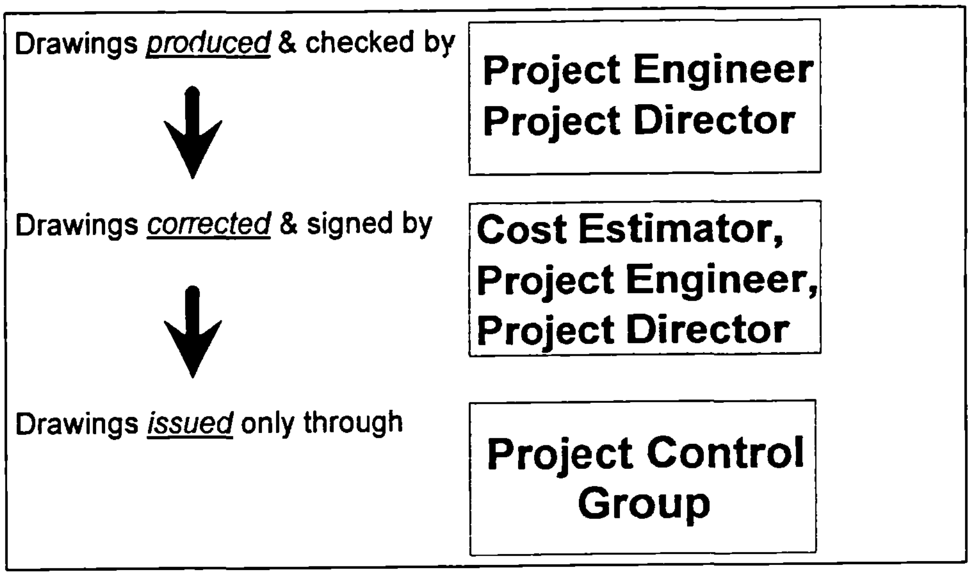


Figure 5.11 PAE's control of design quality (Source, Ove Arup)

The responsibilities of the personnel specified are divided into two groups.

1. **Operating the quality planning procedures**

PQP Auditor	Internal audits of the project quality planning procedures. Issue the records of audits. Recommends corrective action.
Technical Coordinator	Direct responsibility for maintenance and amendment of project quality plan. Reviewing quality procedures and overseeing their use. Maintaining quality records

Design Team	Scheduling reviews and ensuring that records are kept and submitted. Identifies design activities, assignments and interfaces within team. Monitors and maintains the procedures within their team.
Drawing Controller	Responsible for the control of the project document identification systems for its drawings, and its database operation.
Document Controller	Responsible for the control of all project documents, except drawings.

2. Assessing quality of the design work

Design Directors	Overall responsibility for the directions and control of design work and technical standards on the project.
Design Executive	Direct responsibility for design and technical standards in their field. Chair major reviews.
Design Team	Responsibility for design work and technical standards within their Project Manager's team. Chair minor reviews. Reviews/approves design outputs within their team.
Design Team Project Architect/ Engineer	Responsible for checking design output in meeting design input requirements in their field. Monitoring adequacy of design input.

The coordination of the design is separated into four levels within the PQP.

Level 1: Master Plan/Scheme Design Coordination

Here the design for individual buildings and facilities were monitored against the approved Master Plan documentation produced by TKLP. The coordination at this level was two-way so that either the design was altered to meet the requirements of the Master Planning documentation, or the Master Planning document was amended in the light of more recent design developments.

Level 2: Elemental Site-Wide Standards Co-ordination

As the scheme and detail design for individual buildings and facilities developed it was required to coordinate and standardise certain elements such as laboratory benching, and cladding.

Level 3: Cross-Team Coordination

Collectively the design teams had the responsibility to achieve a coherent and fully integrated design. This interfacing occurred primarily through the Design Team Project Managers, and Project Architect/Engineers when appropriate, who held regular design management coordination meetings with the Design Directors and Project Director.

Level 4: In-Team Coordination

In-team coordination was seen as the essential element in the design. The coordination activities occurred without outside assistance, through regular in-team design meetings, sessions, and reviews, and through the establishment of clear concepts during the scheme design.

5.8 Design Reviews

The use of design reviews and audits was a quality control tool which ensured the design progress was of satisfactory standard. The PAE defined a design review as:

> 'A formal examination of the design to evaluate the design requirements and the capability of the design to meet these requirements and to identify problems and propose solutions'

A design audit is similarly defined as

> 'A separate internal examination to determine whether design activities and related results comply with planned arrangements and whether these arrangements are effective and are suitable to achieve given objectives'. (Source PAE)

The PAE distinguished between interim design reviews and final design reviews. Interim reviews were held by senior PAE staff and on occasion representatives of GGR during scheme design and detail design. The purpose of the interim review was to recognise blind-spots or undesirable approaches. Final design reviews were held at the conclusion of each stage of phase three and four as shown by figure 5.12. This diagram also detailed the key players who were present during the design stages and whose input was obtained during the review process.

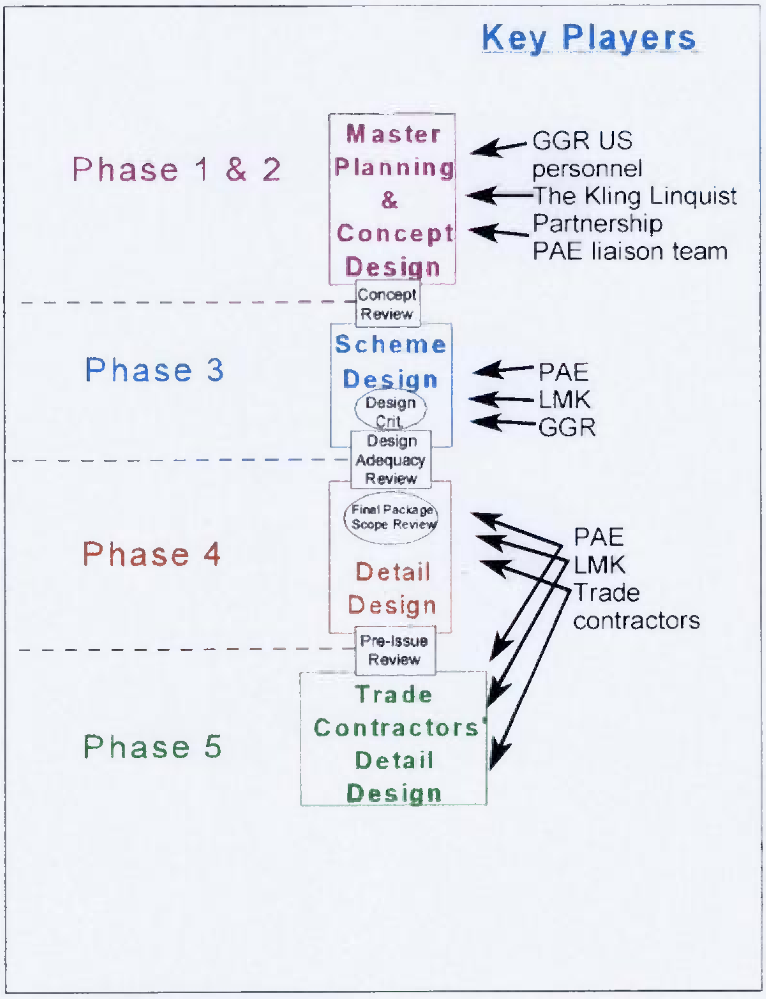


Figure 5.12 Design stages and reviews

These formal, critical reviews were held by the PAE and included participants drawn from relevant disciplines appropriate to the design phase and the factors being reviewed. Representatives from GGR, TKLP, and LMK were in attendance when agreed appropriate.

The key objectives of the design reviews were to ensure, within time and cost constraints that:

- The design met the specified requirements
- Statutory requirements are complied with
- There is adequate supporting documentation to define the design

GGR were acutely aware of the implications of not keeping a tight reign on those who were forming the ideas which would ultimately commit the client to major expense. The familiar dilemma of the majority of total costs being decided upon during the design process and before any construction work takes place required a detailed scrutiny of the way the design was developing. This role was provided by Davis, Langdon and Everest who, as a professional quantity surveying practice were well versed in equating design decisions with financial cost.

The involvement of the construction cost control experts began at scheme design when the design was 30-35% complete and when there was sufficiently detailed information available to allow an itemised breakdown of elemental costs. At this stage the PAE prepared Scheme Design Estimates, which provided information on estimated quantities, man hours and value. As shown in figure 5.13 this point along the horizontal axis corresponded with a funding estimate error of between 5-15% which would ultimately drop to less than 5% at the end of detailed design. This contrasts with a 35% margin of error at the early stages of master planning.

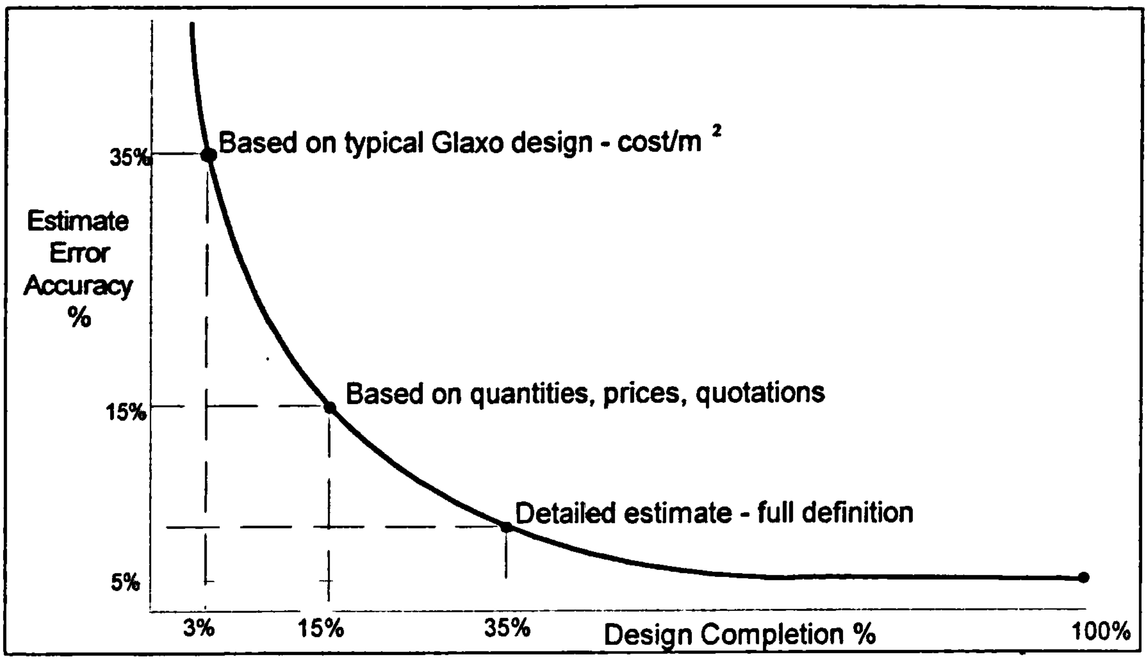


Figure 5.13 Funding strategy and evaluation (Source, Ove Arup)

5.9 Value Engineering

GGR required a separate value engineering exercise to be conducted towards the end of phase three, scheme design. The PAE's interpretation of the objectives for the value engineering study was to identify unnecessary costs, especially those that did not measurably contribute to the quality, function, durability, or GGR's requirements.

The value engineering exercise was considered to have four steps:

1 Information

Gathering information	- What is its function
	- What is the value and cost of the function

2 Speculation

Gathering information	- Is the function necessary
	- What else will perform the function
	- Can some other function be implemented more effectively

3 Analysis

Evaluating alternatives
- What will alternatives cost
- Will alternatives provide equal or superior quality
- Project cost comparison of alternatives compared with proposed design

4 Decision

Discussing the alternatives derived from the analysis, and determining the implementation of the agreed changes.

The remainder of the PQP covers issues of administration and document administration, control of design interfaces with trade contractors, and CAD administration procedures.

5.10 Engineering Quality Control

An early part of the design process was the production of a design schedule detailing and timetabling the key design stages. As the designers were on a cost recovery fee basis it was also necessary for them to provide a manpower estimate of the design and to seek approval from GGR as to the staffing levels. With such a form of contract the fear is that there will be a tendency to over design. This was one of the considerations which led the GGR management team to set up a department of Engineering Quality Control (EQC). The purpose of this department, comprising 12 specialist engineers well versed in the detail of pharmaceutical design, was to scrutirise the output from the PAE and suggest possible alternatives.

Before setting up it was necessary to consider the benefits of providing such an additional level of checking. As there was to be a vast amount of design output (see figure 5.8), a level of resource for this function had to be decided upon in advance. The PAE accepted that GGR did have specialist knowledge in certain areas and agreed to the client vetting of the design.

It was an important consideration that the additional checking did not hamper the design progress or lead to major disruption. The timing of this additional checking was therefore critical as any delay in spotting problems would have led to redesign and all the associated problems. As the EQC engineers identified potential problems they referred them to the project design manager for the area concerned who was responsible for taking any actions. The problems fell into two categories, those which could be incorporated into the design without additional delay and cost and those that required a formal change order to cover them. The vast majority were of the former type and caused little or no disruption to incorporate. Those for which there was a more significant impact were analysed to identify whether they were worth proceeding with.

A simple tracking system was operated to record the number of problems identified, the impact of the problem and the outcome. All problems identified which had a cost implication (addition or saving) were formally costed by the PAE so as to demonstrate the benefit of the scheme. The final figure arrived at for all savings was in the region of £4-5 million which was achieved without compromising the functional content of the design.

5.11 The Use of CAD

A key element of the design was the use of CAD to produce and record the drawn information. GGR required each consortia to nominate the CAD system it intended to use. Ove Arup and Sheppard Robson convinced GGR that there did not exist a single CAD system which had the versatility to fulfil the needs of both architects and engineers. Sheppard Robson employed the Intergraph mainframe system which it had been using for some years. During this time it had stored vast quantities of architectural information on the computer and had built up a considerable database of architectural details. Ove Arup used the Autocad PC based system which allowed more flexibility for service layouts, but which did not have such a large storage facility for details. Although the two systems are fundamentally different, the two design firms convinced GGR that sufficient communication could be established between the two systems to enable them to work effectively. As there was to be substantial concurrent demand for the CAD system 44 PAE workstations were installed in the design offices and at the peak of design activity there were problems in finding suitably qualified operators. The number of CAD stations increased to 76 during the period when trade contractors were detailing the design and producing installation drawings.

5.12 Moving Towards The Construction phase

LMK's organisation chart for the project was adapted to meet the requirements of each particular phase, however a typical chart is given in figure 5.14.

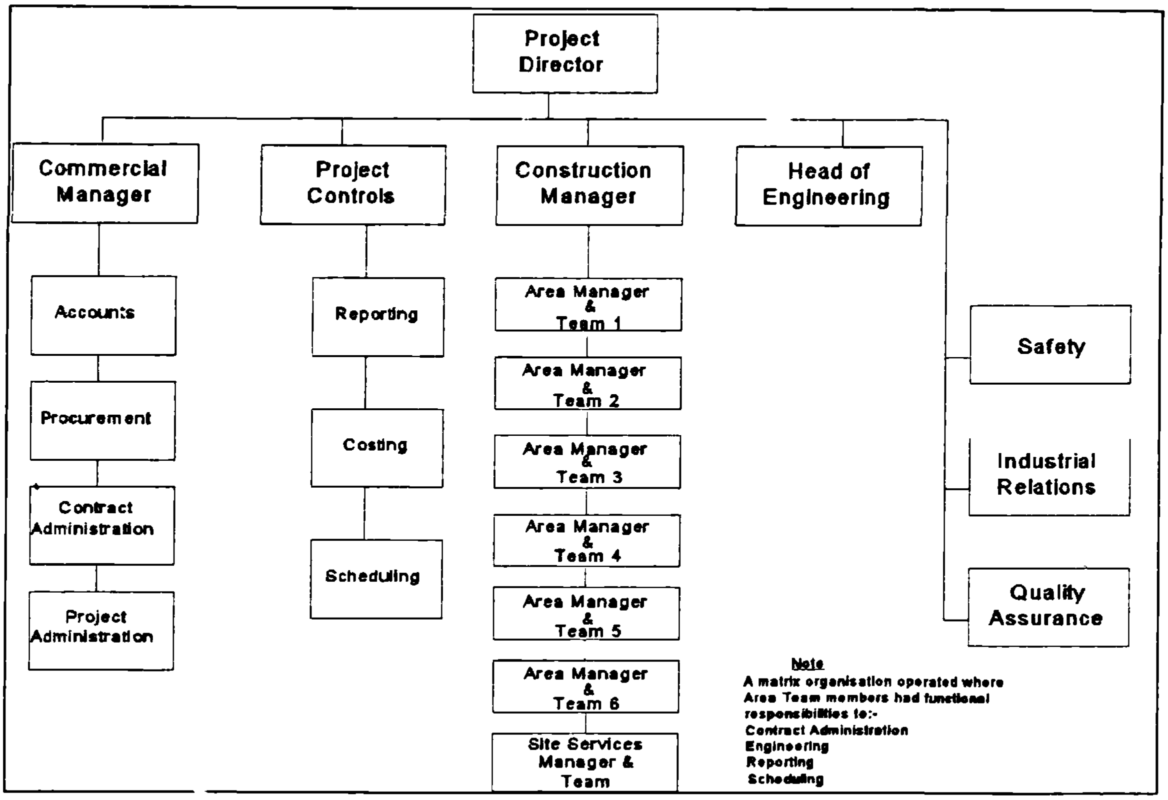


Figure 5.14 LMK organisation chart (Source, LMK)

LMK had the responsibility to produce and monitor progress and ensure that all construction activities occurred in accordance with the plans proposed initially. At the earliest st^ges when the PAE were in scheme design these plans were broad brush and generally indicated the order of construction and approximate durations. As the design progressed so more detail was made available and changes were made to the schedules to reflect this. Once at the tendering stage, subcontractors had to provide schedules for their work providing yet more detail. Therefore by the time the construction phase started in earnest there was a large amount of data available which needed to be used to ensure the necessary progress was made.

LMK and the design managers at PAE converted this design information at the scheme design stage into the Elemental Work Packages (EWP's) which were independent scopes of work and which formed the building blocks on which the latter stages of design and the construction would be monitored. The use of EWP's involved giving the proposed activity a financial cost and a duration calculated in person hours. For the system to operate with any integrity there was a complex exercise of evaluating the Elemental Work Packages so that realistic estimates of person hours and value could be formed.

This exercise was carried out by the scheduling department of LMK which used historical values for different construction activities. LMK were able to provide a highly detailed estimate of the person hour requirements for each activity together with a predicted value. The result of this exercise was the establishment of the Earned Value.

The overall performance of the project was accomplished by utilising an Earned Value system which was used for progress monitoring and payment. Whilst individual activities would be evaluated through the use of the most suitable method, the project as an entity had to use a method which had a common basis. The element used was labour hours. The individual activities percentage completion, how so ever measured, were converted to a percentage of the control budget labour hours completed or earned. Appendix 1a details the various ways that Earned Value was calculated.

As the design was developed in more detail LMK began to collate Elemental Work Packages into works parcels. At this stage LMK's procurement department worked in conjunction with the LMK scheduling department and the PAE so that complete packages could be formed.

Once the detailed design was sufficiently complete works parcels were compiled by LMK, and subcontract documents prepared and made ready for issue to trade contracting companies. The size of the subcontracts meant that many of the same companies involved in the original GGR project were included on the lists of tenderers. Since there was significant overlap between the different buildings, trade contractors were included on several lists but were only considered for more than one contract if they could demonstrate the capability to handle the management and financial issues involved with two or more concurrent projects of this scale.

Although the tenders were of a fixed lump sum nature the trade contractors were required to provide their own estimates of the person hour requirements for all the activities listed as part of the scope of works for that contract. This was in addition to providing the value for each activity. Through analysis of the returned bids LMK were able to spot discrepancies either between different tenders or with their own estimates. As part of the contract, the person hour estimate became the basis on which trade contractor progress was monitored, and payment was made.

The trade contractors and major vendors were contractually required to provide a detailed schedule of milestone/target dates which included the corresponding manpower loadings together with a schedule of values for each month of the contract duration. As well as off/onsite production activities, those subcontracting firms with a design input were required to provide a similarly detailed schedule of design production including milestone and target dates. Those design schedules were to be coordinated with approval periods and all necessary lead in and manufacturing times so that the scheduled start on site date would be met.

LMK were increasingly involved throughout the latter part of scheme design and, throughout detail design, acted as coordinators between the PAE designers and those trade contractors with a design input. The involvement of the trade contractors with the design process was crucial on a fast track project. By combining the general design skills of the PAE designers with the specialist knowledge of the trade contractors the ability to speed the detail design stage was considerable. Such intentions necessitated a number of key factors to be fully considered in advance of this stage. The key factors were the detail of information at the point of overlap between the design team and the trade contractors and the sequencing of construction vis-à-vis the design.

5.13 Standardisation and Procurement

From the outset GGR were insistent on the use of site wide standardisation. Not only was this for the selection of materials and components but also required the design to follow common solutions. The logic behind such a philosophy was obvious - standardisation is both cheaper and simpler than the bespoke equivalent.

The full implications of such a policy are extremely onerous and can have major consequences on the way the whole project is planned. Initially it meant that a number of reviews need to take place so that the common areas of design could be identified. Those areas which were identified were grouped and designed as one by the Central Design Team.

On such a complex project with such a large number of specialist functions that initial process became more difficult. The discipline of mechanical and electrical design for example, required forethought so that common zoning of service voids could be maintained. To ensure full standardisation of design it was necessary to achieve a completely distinct and dedicated commitment from those monitoring the design's development. In conjunction with a standardisation of design, a list of components which could be standardised was produced. This list would therefore be highly correlated with the standardisation of design. If there was a significant element of complexity in a range of similarly standard components then a site wide works package would be created. Hot & Cold rooms and autoclaving facilities are examples of complex, yet common, facilities found throughout the buildings. The initial number of site wide packages was five and consisted only of those elements that were obviously common to the whole project, for example, pre-cast cladding. The result of a more detailed appraisal between the PAE and LMK increased the number of these packages to 96.

5.14 The Construction Phase

a. Project Controls

Monitoring all the information relevant to construction fell across several departments. Design engineers and site managers monitored the daily progress of the trade contractors who were contractually obliged to pass on the previous day period progress record. In addition the project control department carries out random audits to ensure that documented progress corresponds with actual progress.

The reference documents used were schedules and reports which were produced using sophisticated software packages for monitoring, extrapolation or prediction. The myriad of schedules and reports produced by LMK fall under their umbrella heading of 'construction project controls'.

> 'Project controls on the Glaxo project are used to provide timely and accurate analysis and reports on the project cost and schedule objectives.' (Source: LMK Project handbook)

Project controls encompass the areas of estimating, cost engineering, planning and scheduling and data processing, and provide all concerned parties both with the information necessary to ensure all objectives are met. The variety of concerned parties, from GGR, who are mainly concerned with global objectives through to LMK area managers whose preoccupation is with short term detailed schedules for a specific area, require significant flexibility in the production of relevant information. Core controls were used for auditing, technical support and report coordination for the total project. They were produced by a centralised department responsible for overseeing the data gathering and processing for the construction phase. Technical and procedural reporting are the responsibility of the LMK Area Project Control Departments.

b. Scheduling Level Overview

The key element of the scheduling is the Works Breakdown Structure (WBS) which is the hierarchical structure used to show ever increasing detail of the construction. The detailed breakdown of the Works Breakdown Structure is given in appendix 1b

Monthly quantity and manpower reports including actual hours worked, actual quantities installed, productivity, control budgets and Estimate To Complete (ETC) values were fed into the project report. Estimate At Complete (EAC) values were also provided, based on trend analysis of current progress. The total cost implied for each monthly report was calculated by forecasting subcontract values and utilising Estimate At Complete labour hours to establish subcontract growth and future subcontract costs. In addition, forecasts for other cost elements such as equipment, and materials provide the Estimate At Complete figures were calculated.

For the cost control function to maintain its validity there was a need to ensure that accurate measures of work in progress (WIP) were kept. The methods used were dependent upon the type of work to be measured. Six methods of measuring WIP were used and these are detailed in Appendix 1c.

c. Construction Cost Control

The importance of the cost control systems used was fundamental to the management culture used on the Glaxo project. By keeping costs linked to the actual level of site production there was an ability to bring all issues back to a financial cost and its implication. By having the LMK cost control department produce information in conjunction with the area management and scheduling departments it was clear to all if there was a problem.

The use of such reporting enabled the PAE and LMK management to fully involve themselves in the activities of the trade contractors and to deal with any problems with a unified voice. This information was far more powerful when applied to forecasting future situations than just resolving the current problems.

The initial forecasts were the responsibility of the PAE. The designers initially set the parameters for the design based on the clients budget. As the design progressed so there were a number of clear breakpoints, in the form of design reviews, where the design was costed and forecasts made as to the outturn cost. The PAE ended its responsibility for forecasting cost as the design formally passed to LMK.

As construction projects are dynamic, conditions often arise which are not allowed for and which lead to claims for additional work or disruption to the existing works. When such circumstances occur the general tendency in the UK is to act to resolve the practical problems but to leave the financial implications to a later date. Given such circumstances the ability to forecast potential problem areas would greatly assist in preparing budgetary allocations for the future. The cost control department must be aware of the following issues when considering cost forecasting:

1. Knowledge of design completeness
2. Potential cost impacts of probable changes
3. Final cost of pending changes
4. Forthcoming unavoidable field delays which may impact trade contractors ability beyond their control
5. Latent conditions not yet identified by formal requests for changes
6. Experience of the typical growth pattern for certain types of subcontract (M&E prior to start up)

In addition to the financial cost, performance of the subcontractor could be forecast using extrapolation of historical and current information. As labour hours were recorded as part of the progress monitoring it was a relatively straightforward exercise to plot actual performance against that predicted by both the trade contractor and LMK.

Where significant deficiencies occur (>10% for a consistent period) the trade contractor was advised that a shortfall was occurring which would lead to both increased future pressure and a lack of immediate cash flow. This objective monitoring by LMK quickly and clearly identified problem areas. This was brought to the attention of the trade contractor's site management often before they were aware of the problem.

As the scale of operations at Glaxo was so great there was a need to prioritise the operations of the trade contractors so that resources were concentrated on monitoring the most important tasks.

The product of forecasting was reports detailing expected future trends. These reports would have ideally reported all items to be on or below budget and running on or ahead of schedule. Where the opposite occurred a variance report accompanied the forecast to explain the cause of the problem. Dependent upon the size of the discrepancy the variance report may have been as brief as a couple of sentences or where more serious, may have been a full report with additional back-up documentation.

By their nature lump sum contracts are relatively straightforward to administer as the emphasis is on the trade contractor to resolve all problems contained within the scope of the works. It is only where the scope of the works is enlarged, or where there are a large number of changes, that there is any necessity to control additional costs. If there are a large number of change orders being made to a particular trade contractor then this would tend to indicate that there is a more deep rooted problem requiring attention. It would be foolhardy to generalise the remedy to such a situation, however the first stage would be to discuss the situation with all involved parties at the earliest opportunity.

The problem of poor performance is more easily addressed by management staff than cost control. Again the first stage after the identification of the problem is to have a frank discussion between all concerned parties. Corrective action on the Glaxo project was only considered when the subcontractor's performance was poor (>10% variance between expected and that submitted by the subcontractor), and when the subcontractor's level of completed work lay within the range 20-80%. The purpose of all monitoring was to resolve problems at the earliest opportunity.

Audits of core areas of the various buildings were carried out as a matter of routine, although not to any published timetable. The purpose of the audit was to ensure that the key areas of costing, scheduling and computer application were being effectively maintained. The audits were carried out on a rotational basis and each core area would be expected to be checked six times a year. The audit reports were only circulated on a need to know basis but would have included the area project management staff togethei with the LMK and GGR project control managers.

The volume of information produced for the construction administration is great but this volume is necessary. This is because those responsible for ensuring that the project remains on or ahead of the timetable set and agreed need to be kept fully aware of current changes in what is a very dynamic situation. Through the use of integrated information not only is time monitored, but so is cost. Thus acceleration options can be costed and various alternative scenarios computed. The use of Information Technology in this area is crucial. LMK employed a system of computer databases which 'fed' information to a sophisticated project management program which could tailor its output to what was required. This technology allowed great freedom in the production of schedules and reports. The information produced is, however, only as good as the data on which it is based. LMK appreciated this and employed many staff who continually monitored progress. In addition, the subcontractors had the responsibility of providing detailed reports of their progress which was agreed and subsequently used.

The scheduling departments activities were interwoven with those of the cost control department and the construction managers. Through such integration complex reports were available which ensured that all those on whom responsibility for the project fell were equipped with the necessary information on which to act. As GGR closely monitored all the activities on the project there was little point in attempting to portray matters other than as they were. This realisation necessitated an open attitude towards problem solving. Although comprehensive, the systems operated was developed to cover such a wide range of tasks that there was the problem of the sheer volume of generated information.

d. Quality Control

The Glaxo project introduced a new approach to the issues involved with quality. Specifically the contracts drawn up made quality control the responsibility of the party carrying out the work and therefore required a dedication to self policing. It was contractually required that those in charge of the execution of the various stages of the project were primarily responsible for accepting and taking responsibility for all work carried out during those stages. Thus the PAE were required to ensure that all design information was checked and approved before release regardless of which design company it came from. Similarly, but more significantly, LMK were responsible for inspecting and accepting all construction work carried out by the trade contractors, with no Clerks of Works or other approval required from the PAE.

By creating such an environment, GGR placed a great deal of additional responsibility with the main players on this project. The PAE and LMK had to employ specialists to check the work carried out in order to ensure that it met the standards or specifications. The use of in-house inspectors with formal powers challenged the traditional attitudes. As the companies employed were all highly regarded professional firms, the possibility of abusing such responsibility was not viable. Whereas traditionally there has been a confrontational environment between those who produce the work and those who accept it, by bringing this boundary within the remit of the one organisation there is an overriding desire to ensure that the work is acceptable

The situation as described did not release the various specialist sub-groups from their own responsibility for ensuring that all work carried out is to the required standards. Individual designers or trade contractors had a duty of care to provide work that was acceptable. If this work was not, it was they who will have to do any rework or suffer the consequences of others rectifying poor work for them.

Ensuring that the trade contractors design input was controlled, which was carried out in the same offices as the PAE, raised new problems. Here there was an overlap of responsibility between LMK who were responsible for the management of the trade contractors and those from the PAE who needed to check the validity and suitability of the design work carried out. This period was critical to the subsequent success of the project as the complex matrix of information needed committed monitoring and management. In addition to the PAE and LMK, GGR also kept a watching brief on the activities of the specialist designers and were able to advise on matters of global concern whilst leaving the detail to those with more expert knowledge. Once physical production started the emphasis switched to the capabilities of the suppliers and trade contractors.

5.15 Quality Assurance

Figure 5.15, on the following page, illustrates the structure of the QA documents used during the construction stage of the Glaxo project.

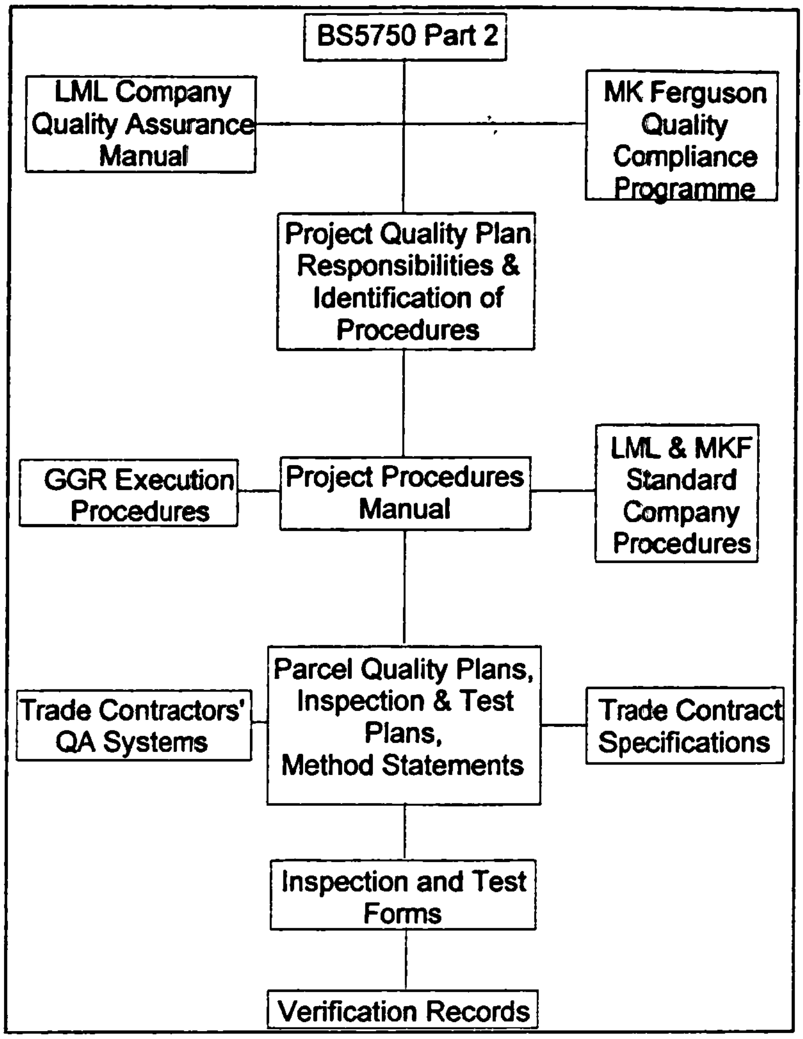


Figure 5.15 Quality assurance systems (Source, LMK)

The documentation which formed the quality assurance requirements on the Glaxo project was based on two principles. The first was the generally accepted international standard of ISO 9000 which is incorporated within the British Standard 5750. In addition Glaxo had developed their own quality standards which they required all the major players to incorporate. For the construction phase, both LML and MKF submitted quality plans which accorded with Part 2 of BS 5750. These general documents were the basis for the Project Quality Plan. Having established a Quality Plan the project coalition set up a procedures manual which detailed how the various functional elements of the project would operate. Here GGR provided certain guidelines through the use of their execution procedures document.

The next level of QA documents was concerned with the subcontractors carrying out permanent works on the site being required to demonstrate a comprehensive understanding of QA procedures. This requirement was found in each trade contractor's specification as well as being stressed in all pre-qualification information. In many cases the standard was set through the use of BS 5750 parts 1, 2 or 3 as applicable.

For such a large and complex project as this the selection of suppliers and contractors was critical. Sourcing for these companies took place worldwide although the majority of companies were selected from the UK market. The initial selection was based upon track record, financial soundness, and commitment to the project. GGR vetted the list of proposed companies selected by LMK to receive bids and required documentation covering various factual data on each company together with seeking detailed answers from previous users of the companies services who acted as referees.

Part of the pre-bid selection criteria for all direct suppliers and trade contractors was their ability to demonstrate a strict regime of quality. This necessitated the production of quality statements that, for successful tenderers, became comprehensive quality plans. These documents, covering both inspection and testing details together with documentary quality assurance routines were thoroughly vetted by the LMK quality assurance team together with GGR personnel. The acceptance of quality plans was the start of the complex quality procedures which was subsequently followed. This paper intensive task was strictly enforced and continually audited to ensure that the quality standards were maintained.

Works parcels were graded according to their importance and impact on the overall project, for example, services parcels were given a higher grading than general painting. As there were some extremely complex installations, particularly related to the M&E installation, the need for comprehensive testing and monitoring systems was paramount. Other aspects of the works, such as the production of the pre-cast structural elements (procured from the East coast of the USA) were also given a high grade so as ensure that all necessary checks were performed in order to guarantee a consistently high quality delivery.

The requirements from those with the highest grading was comprehensive. Where the quality control of components or systems necessitated formalised third party testing, LMK and GGR were contractually invited to witness the tests. A contractual clause allowed GGR or its representative access to all the works at all times for the purposes of inspection or verification. Verification may have consisted of documentation checks, material or product review or for the witnessing of tests as specified. Those activities could take place on the site or at the supplier's or trade contractor's premises. Key documents such as test reports were circulated to all concerned but the remainder were held by suppliers or trade contractors.

In order to ensure compliance with the procedures manual, QA audits were carried out by the LMK QA staff. Whilst the execution phase is important the QA documentation procedures were of greatest importance during the testing and commissioning phase. At this stage witnessed tests and commissioning approvals were critical to the successful handover. As the installation involved sensitive and delicate equipment, LMK had dedicated specialist staff to ensure continual maintenance and caretaking of such items prior to full commissioning. All the routine maintenance records therefore provide part of the QA documentation.

5.16 Analysis of the Glaxo Project

a. Project Controls

When considering why this project may differ from many others it is necessary to consider firstly the type of client. Glaxo is a world player in pharmaceutical research and production and has much previous experience in constructing and operating complex process buildings. Glaxo's initial requirement for new UK based research and development headquarters was considered to be adequately administered using UK based construction methods and systems. Having started down this route it took strong leadership to bring the project to a halt and to completely re-configure it. The dismissal of AMEC and the termination of all the design and build or design and manage contracts were expensive both in terms of aborted costs and delay to the initially intended programme.

The clear emphasis placed by GGR on its key project personnel who were experienced in either the US petro-chemical industry or US construction has been fundamental to the subsequent approach. The level of control placed on all parties by Glaxo was wide ranging and forced the various players to adopt methods of management not previously utilised. The appointment of the PAE and Principal Contractor on time based forms of contract was a clear example of this approach. GGR required the majority of elements of the management of the project to be visible and open to inspection. In order to facilitate this, Glaxo acted as the banker for non-personnel resources employed by the other main players including accommodation, furniture, computers and office equipment. GGR was comprehensively staffed and during the construction stage, for example, matched the LMK staff on an approximate basis of 1:2 (very approximate figures are GGR 100 : LMK 170) so that they were fully aware of the progress and performance of all parties.

Glaxo introduced time based recoverable forms of contract for the design team and principal contractor. This form of contract requires the various parties to estimate fully the staff resources which will be utilised on the project. Glaxo then vetted these selected personnel and approved budgets. Having been selected, the parties were required to formally record the time spent by their staff on the project and to submit these records to Glaxo. Glaxo therefore had an effective way of monitoring how the various parties are performing compared to the original estimates.

The reporting regime used by Glaxo was far more onerous than usually found in the UK. Glaxo required a formally submitted report on all aspects of the project each month. This report, running to many hundreds of pages, provided both overall summary and itemised breakdowns for all aspects of the project. In addition there were numerous ad-hoc reports and regular meetings to consider specific aspects. LMK held regular weekly or fortnightly meetings with the trade contractors and Glaxo could, and did, attend the most important of these.

b. Detail Design

The detail design period at Glaxo included a critical period of overlap between the PAE design team, LMK, and trade contractors who had a design input. Apart from the many technical problems and queries which arose between the various specialists and designers it became clear that there was a more fundamental problem regarding the level of information provided at the point of overlap.

One of the problems encountered was due to the various definitions of 'complete design'. All parties, from the client whose project managers are versed in US construction and the petro-chemical industry, to the UK trade contractor with a design responsibility, had a different view. Whilst a contract may attempt to define such terms commonly for all, there will be many circumstances which require practical solutions to be sought which are either outside this definition or contrary to a particular party's interpretation. Where such fundamental definitions are not explicitly defined major disagreements can occur. In these situations the traditions and experience of the participants will dictate the response.

Glaxo, as previously stated, elected to procure all trade contractors on a fixed lump sum basis while providing the trade contractors with enough information to make it as easy as possible for them to select their own suppliers etc. The problem which was experienced because of this was that the level of information required is enormous and the delivery of that information is critical. As trade contractors had tendered on the basis of 'complete design' they had allowed for the production of fabrication and installation drawings based on fully detailed design information from the PAE. However when this stage commenced it became clear that there was a discrepancy in the information available. Trade contractors found that the PAE design was not detailed enough for them to simply convert into fabrication or installation drawings. The PAE's view was that they had taken the design up to the point where the trade contractors could take over. This disagreement slowed progress and caused many problems for the design managers from all parties.

c. The Use of CAD

As the design continued to progress the use of the CAD systems by the designers proved to be more problematical than expected. Initially the concept was taken into scheme design jointly by the architects and the engineers. Having established a common basis, the two design organisations then started to develop the scheme design on their own CAD systems. Glaxo required that formal meetings were held to pool the information. This mainly required the service engineers to lay service installations onto backgrounds provided by the architects. Another formal design review was carried out at the end of detail design prior to going out to tender for the trade contractors. It was at this stage that the design had to be complete for the purposes of lump sum tendering. Should there be any discrepancies in the design then these would eventually be discovered and could cause significant disruption. The problems which began to appear concerned the level of design information available at the time the works parcels were let.

After the trade contractors had been awarded the contracts it was found that the supposedly fully coordinated drawings were being supplemented with revised drawings coming from only one member of the design team. This caused considerable confusion as the trade contractors were in receipt of conflicting information. The cause of this confusion was that there was the ongoing refinement to the design being carried out by the various members of the PAE.

Since these alterations and amendments were being produced on separate CAD systems within a very strict timetable, they were released as additional supplementary information without necessarily being fully integrated. The trade contractors were required to develop their designs on fully coordinated information and hence drew attention to this anomaly. The only way that the problem was resolved was for more frequently held design update meetings to be held by the members of the PAE. The difference between the theoretical operation of the two independent CAD systems and the actual situation can be seen in figure 5.16 a and b.

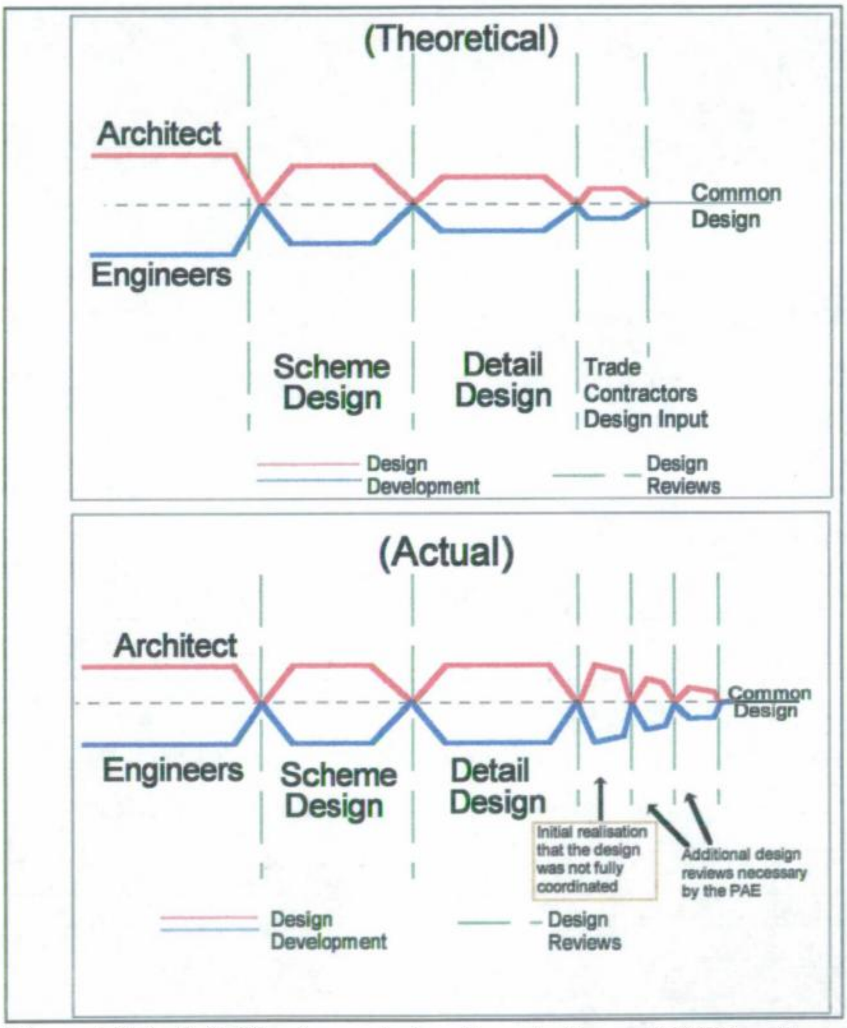


Figure 5.16a & b The theoretical vs the actual use of CAD systems

In the figure 5.16a the design development is commenced independently by the architects and the engineers based on the information available from the concept design phase. At each of the formal reviews the design is checked and information swapped between the two systems and then continually updated. At each subsequent review the gap between the two designs narrows and, through continual data swapping, eventually becomes a common design. This point was clearly meant to occur at the time the trade contractors were being procured. Because of the substantial amount of information generated by the PAE and the considerable system resources required to swap data between two fundamentally different systems, what actually occurred, as shown in figure 5.16b, was different. Although design reviews were held at the agreed times, the demand for progress on all aspects of the design led to a concentration on individual aspects of the design at the expense of communicating this to those working on other areas of the design. Although key points were communicated, a majority of design development information stayed on the CAD system on which it was originally input. The realisation occurred when the trade contractors received this conflicting information and reported it. The solution was a number of hastily arranged reviews and the supplementing of CAD with the manual transcribing of information. This CAD updating caused increased pressures on the design team and the CAD systems, as they had not been designed for such continual information communication and led to inevitable delays.

d. The Procurement Problem

GGR insisted on fixed lump sum contracts for the works packages. This form of tendering itself has implications for the design as it requires the design to be fully considered and detailed before the tendering process can begin. This meant that the design had to be based on generic information. This caused a conflict between the original idea of standardisation of design and the practical development of the design. As the final calculations for the coordination of components, particularly service related items such as variable air volume boxes, needs to take into account the actual dimensions of unit, it is necessary to stipulate which particular manufacturer's unit is being used. This problem is compounded when the unit considered is a bespoke item, designed to meet specified performance specifications. Thus boiler size, for example, is calculated according to the heat output required from the heating system. The physical dimensions of a boiler with the same heat output capacity may, however, vary considerably from manufacturer to manufacturer. The conflict occurs where tendering trade contractors, aware of the importance of low cost bids, use the cheapest suppliers, whose components may be substantially different from those intended by the designers. Initially the PAE produced highly detailed information including performance specifications but which did not specify particular manufacturers.

As GGR had maintained the stance of fixed lump sum bids from the outset, both the designers and LMK organised certain key aspects of the project accordingly. For the PAE, the emphasis was to generate fully detailed information in accordance with the tendering programme agreed by all parties. LMK arranged the detail of the procurement programme around these dates and concentrated on defining the scope for each of the works packages.

As the tendering process for the trade contractors commenced there was a realisation that there were likely to be substantial problems related to additional information requirements. The probability of many trade contractors needing detailed information on similar details led to a perception of this previously unrecognised problem. From the designers viewpoint the major consequence was that the problem could be reduced dramatically if there was greater standardisation of design elements at a much more detailed level. The procurement policy for the project also needed to be changed if the problem was to be reduced.

It became increasingly clear that to satisfy the detailed performance specifications being demanded there was going to be a significant element of specialist component design required. This had several effects. It would increase the complexity of the tendering process as it would necessitate the works contractors getting involved in specialist component design as part of their tendering process. Furthermore the works contractors were to be required to develop their own installation drawings which were to be coordinated with other relevant contractors. As most of these installation drawings could proceed only after the components had been confirmed and supply assured, there were likely to be serious delays as the timing of the procurement stage had not fully allowed for the scenario where contractor A could not complete their installation drawings as they required details of specialist components which had to be provided by contractor B, who was not procured at that time.

This realisation led to a significant level of concern at executive level as there appeared to be a potential disaster looming. The outcome of discussions was for an intensive period of detailed technical discussion to take place between LMK and PAE. The purpose of such discussions was to revise the scope of the works packages, the coordination requirements between the contractors, and the way that the design affected these.

Although unplanned, the management team from LMK and the PAE began to alter workloads and change the design emphasis so that those trade contractors initially involved were able to continue working. As more works parcels were let so the amount of specialist information increased and the pressures began to ease. At the peak there were in excess of 70 trade contractor designers and engineers working alongside the PAE designers. The learning curve experienced by the design engineering managers from the PAE and LMK was significant and was a fundamental influence on the way the design approach altered.

Significantly there was a need for the designers to enter early discussions with specialist suppliers so that specific details of components could be included as part of the information to tenderers for the works packages. Clearly this information could only be included if the specialist suppliers were included as nominated suppliers to the works package tenderers. This required GGR to alter the policy of clear cut fixed lump sum tendering and to enter negotiations with these suppliers to secure the best terms and conditions for these components. As this process continued the procurement policy adopted by LMK was forced to change from one dominated by purely pricing interests to a far more technically orientated operation. This complex situation is illustrated in figure 5.17, on the following page. In this diagram the green line represents the generic design principle adopted initially by the PAE following GGR's desire to use full lump sum tendering with no nomination of suppliers or contractors. Following the stages depicted the design develops until enough detail information is available to appoint a main trade contractor (May '92 - July '92). There then follows a lengthy period of design development where the trade contractor has to alter the design to allow for the specific components and sub-suppliers which have been included in the price which secured the tender (July '92 - Feb '93). By February 1993 fabrication and installation can commence but full information is not available until May 1993. This problem, which was incurred to varying degrees by the majority of trade contractors with a design input, forced a change in policy by GGR and a revision to the way in which the design was developed by the PAE.

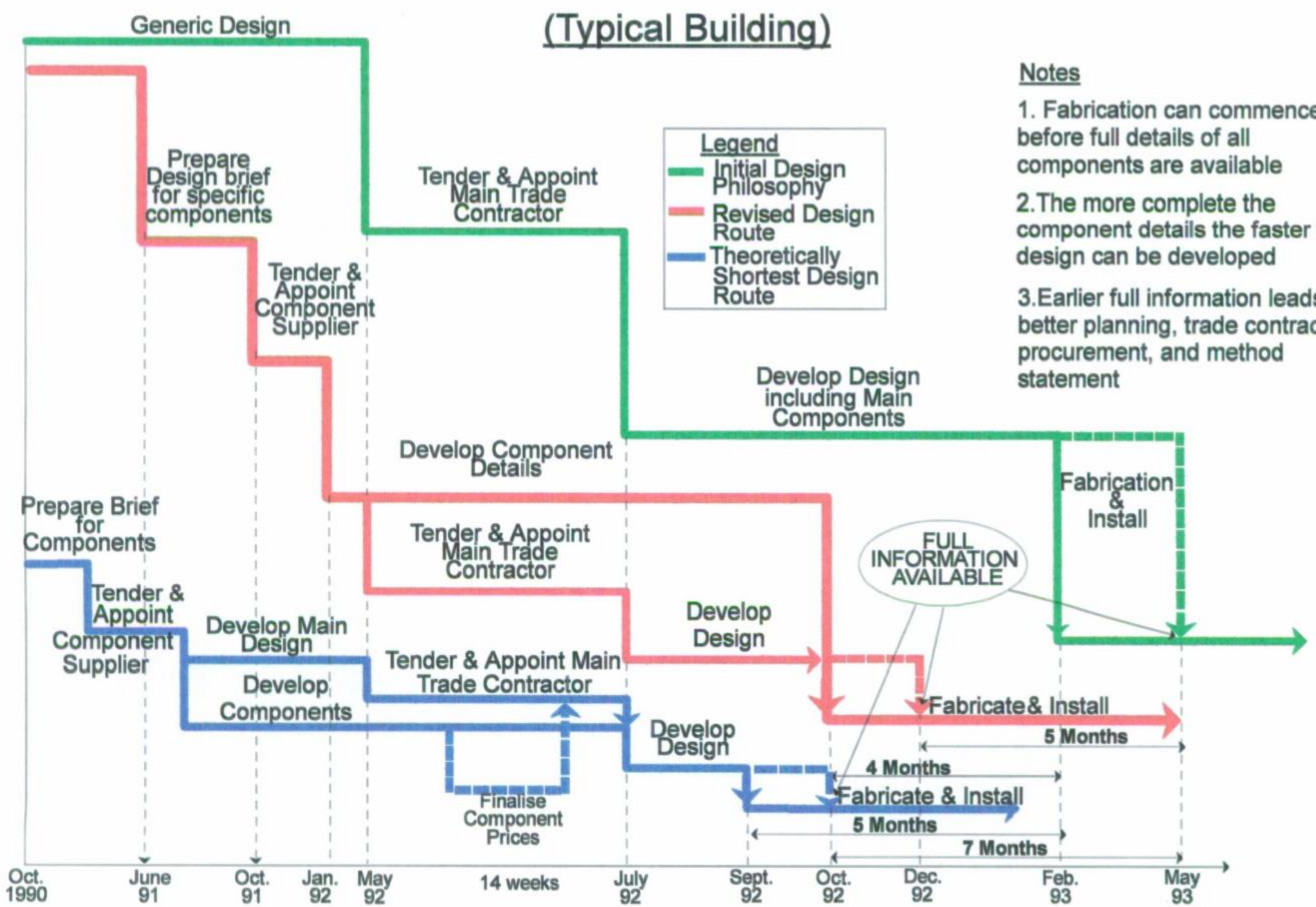


Figure 5.17 Design routes for Glaxo Source: Adapted from LMK info.

The red line indicates this change and demonstrates the time saved compared with the original policy. Firstly a design brief was prepared for the specific components which would be required within the scope of works for the trade contractor's works parcel. This early design development (June '91-Oct. '91) was followed by the tendering and appointment of a component supplier. Once appointed (Jan '92) the PAE continued to develop the main design including the specific details obtained from the component supplier. At the same time the tendering and appointment of the main trade contractor could commence. This is shown as commencing at the same time as in the original case (May '92) because the strategic change took time to implement. Once the main trade contractor was procured (July '92) two sets of design development took place concurrently. Firstly the PAE continued to develop the principal design. Secondly, the trade contractor worked on the detailed installation and fabrication drawings. This combined exercise is completed some five months ahead of the original strategy (Dec. '92 compared with May '93).

Extrapolating the logic of these first two design development routes, the managers at LMK postulated a theoretical approach to the problem. The blue line indicates the quickest route for design development on a project with parameters similar to the Glaxo project. In this scenario the philosophy behind the design is mutual development by specialists. Therefore the design in principle allows for early input by component suppliers who assist in the development of the overall design by allowing 'firm' data to be incorporated. Thus at an early stage, component designers are brought on board and work closely with the main design team before the tender and appointment of the main trade contractor. During this technical design development stage commercial discussions would be ongoing to secure prices for the components which would affectively be specified to the main trade contractor. Once the main trade contractor was procured, a shortened final design period would be required to incorporate the design team's work with that of the component supplier and to produce installation drawings only. Allowing for the timescales experienced at Glaxo it would be expected that such a design and procurement policy would have saved seven months compared with what originally took place, which represents nearly one quarter of the total development time.

The overall effect of this set of events was a tremendous increase in activity by both the PAE and LMK. It is important to remember that this situation occurred during a critical phase of the project and at a time when any delay would have severe consequences. It was only through a great deal of applied hard work and combination of specialist skills that the problem was contained. The early works packages did suffer delay and a degree of confusion and were let with less than full information, however, the later packages received the benefit of this additional effort and had fewer areas of contention.

Ultimately the confusion necessitated the re-coordination of the detailed M&E trade contractors' designs and a party had to be made responsible for this task. LMK advised that the various contractors carrying out the mechanical contracts should carry out this task as they had the most inflexible of installations. However, Glaxo chose to appoint the PAE to this role. This additional coordination was underwritten by Glaxo as there was now an element of risk involved. Although the problems raised by the trade contractors were surmountable, there was an additional delay whilst the design was resolved.

Once on board the key trade contractors began the process of fully detailing the design in order to produce their own working drawings. This work was coordinated by PAE design coordinators who were distinct from the creative PAE design team. At the same time as the design was being enhanced, orders were placed by the trade contractors with component suppliers for items which would have a long lead period.

e. The Use of Client Specialists : Engineering Quality Control

This checking of the design by expert users or advisors is not new although it is not a common feature of the UK design process. However the formalised way in which this monitoring was organised, and the backing which it received from senior managers meant that a significant difference was made to the design process. Although organised differently, the benefits of EQC are similar in many ways to those of Value Engineering. The significant difference is that the EQC was a piecemeal process rather than a concentrated effort as found with most VE exercises. A clear distinction is made between the VE exercises carried out on this project and the EQC system. Whilst the VE exercises carried out by the PAE considered singly important aspects, the number of potential problems and costs which were offset through the use of EQC suggests that it is a system worth operating in tandem with other design review techniques. The scope for such systems varies according to the type of project and its complexity, but in the UK, where there is a tradition of over specification in routine designs, the prospect of identifying areas of possible saving through the use of EQC or similar is a definite possibility.

5.17 Opinions Drawn From Analysis

The problems encountered during the detail design period between the PAE, LMK and the trade contractors expose a weakness in the system employed in the UK. Where situations occur which are outside the remit of the word of the contract there is an immediate claim for additional negotiation which has led to the rise of the so called 'claims culture'. This form of operating is both time consuming and expensive, requiring comprehensive documentation, administrative experts, and the generation of a confrontational atmosphere.

Although the project has now been successfully completed, the debate as to who acted correctly continued. Various viewpoints concerning the contractual responsibilities have now been established which demonstrate that there must have been an initial element of misunderstanding or confusion. It is interesting to consider that at the time the problem occurred there was a determination to get the problems resolved. Although this attitude may have been held by those who saw the potential disruption which would follow if no action was taken, it is not typical of the way in which contracts are normally executed. Indeed those who financially administer such contracts are often pitted against their own colleagues who are responsible for managing the daily activities. The reasons for this would provide a subject worthy of separate study but are likely to be strongly linked to the predominance of competitive tendering where competition forces prices down and leads to a highly adversarial nature to be adopted to all unclear situations.

In hindsight it would have been more straightforward for the designers to have established at the earliest opportunity all those specific elements and components which would have to be incorporated into the trade contractor's design. Whilst such nomination of a supplier is not new it is normally constrained to highly specialist products. On a project as complex as Glaxo the number of components which fall into this category number in the hundreds and range from types of light fittings to air handling units and VAV boxes.

For the designers to be able to provide such detail Glaxo, as the client, would first have to be satisfied that by so doing they would not be costing themselves a great deal. This could be achieved only if they were prepared and able to enter into commercial discussions with these suppliers so that they could secure the best price. This would not be easy as they, like most clients, would not be repeat order customers, and hence would not have a prior relationship with the suppliers.

During the Glaxo project the principle of design did change from a generic design, where no components were specified, to the 'specialist' design where specific components were specified. A consequence of this review was that the number of site wide packages was significantly increased. By increasing the number of universal packages, the time saved in developing individual designs was considerable. For the Glaxo project, the change in design philosophy saved in the order of five months. The change of policy complicated the issue of responsibility from Glaxo's viewpoint but did not, of itself, lead to more expense. Through previous discussions with the designers, Glaxo, and the suppliers established the price of the components in advance. Furthermore, as the size of orders for similar components would have increased it is reasonable to assume that economies of scale would hold, or reduce, the unit price.

The reasons for such a change were to speed the process and overcome the delays being encountered at the early stages of trade contractor's design. However, selection of suppliers by GGR was not rushed as the commercial considerations of the best conditions and price for supply had to be agreed. This commercial negotiation, a skill in itself, had to be acquired, honed and implemented.

As there are disadvantages to both generic and nominated design there is an important question of how to resolve this area. The construction companies' experience and expertise is at present lost in this process. Procurement is seen by construction companies as a purely commercial discipline with minimal input from the technical experts. By combining these technical experts with commercially astute buyers, the designers and an expert client or representative, there must be scope for achieving significant improvements in time, cost and performance.

Without such a facility there will always be the dilemma faced by those in Glaxo's position as to whether they should avoid delay and nominate suppliers or whether to allow the trade contractors to negotiate the best price with the supplier but run the risk of delays in completing the design.

5.18 The next stage

Having explored the primary issues associated with the management of the design which affected the outcome of the Glaxo project, it is now necessary to consider how to explore the research question with more rigour. The value of a case study, as demonstrated by the above description of the Glaxo case, allows insight into the micro world of a project, but does little to illuminate the wider world of projects in general. To provides such illumination social scientists have an ever expanding armoury of research methods and tools which they can deploy. In the next chapter the focus will be on exploring the area of design management. The underlying belief behind this exploration, drawn from the gap analysis model, is that there is a need to understand the importance of individual perception, as it has been demonstrated in chapter three, as well as in the Glaxo case, that it is the client's perception which is of overall importance in judging whether a project achieves a successful status.

Chapter Six
Methodological Approach

6.1 Introduction

Following the discussion on the issues raised in the exploration of this research question, attention is now focussed on the methodological approach which will be used. The research question, centring on attempting to understand the detail of the *process* which occurs during the management of the design stages, is located in the academic fields of management science and the social sciences, and has not been a focus of much previous research. After completing the background reading, it was clear that for this research to be of value, the form of methodology had to be suitable for gathering data from which an answer to the question could be made. Given that the question is fundamentally how the human process of information flows and decision making is understood by those involved during the design management process, the choice of methodology was from a set which allowed the handling of rich unbounded data, which was capable of being used in an exploratory context with an objective of ultimate theory building. This raised the first choice, namely between quantitative or qualitative methodologies.

6.2 The qualitative vs quantitative debate

Bryman (1988) suggests that the basic choice of methodological approach, between quantitative and qualitative techniques, is largely influenced by the type of research question being asked. Quantitative techniques, which generally follow a natural science approach, seek to determine the validity of models, theories, and hypotheses, through the use of data capable of being analysed using a vast array of statistical based techniques. As computers are invariably used to carry out highly complex statistical analyses, there is a great temptation to automatically follow this route, generating numerical data which is then processed by one of a number of PC, Macintosh or workstation based statistical packages, yielding both graphical and numerical results. The use of quantitative techniques is, however, only useful in the social sciences when the models, theories, and hypotheses have been carefully considered. If there is only partial understanding of the concepts, or strong bias in the formulation of the models, then the data collected will generally tend to reflect this.

In the social sciences there is a widespread use of surveys which seek to record, from suitably large samples, a series of responses which can be converted into numerical form and then subjected to testing. If the initial model, on which the survey is based, fails to consider all the key variables, then the results may demonstrate that the tested hypothesis is correct, but not that the hypothesis is a full explanation of the problem. Quantitative methods cannot alleviate the need for reason and understanding. Thus there is a compelling argument to fully consider the formulation of a testable theory or model as being as critical as the testing. There will also be situations, especially within the social sciences, where there are phenomena which are not amenable to standard quantitative methods.

The result is one clear justification for non-quantitative methods involving qualitative methods which are not just enablers for quantitative research, and therefore second rate. The capacity of qualitative research to expose actors' meanings and interpretations is itself a valid contribution. Whilst many researchers using qualitative methods will acknowledge that their work may ultimately be capable of quantitative testing, this should not imply that until verified, the work is of no consequence. Indeed such qualitative research exposes the likely dependent variables upon which most theoretical model building depends.

Qualitative research achieves far better results when its inherent flexibility is utilised to the full. This flexibility manifests itself in the way in which the researcher plans the research. The most important consideration is that of adapting the research to fit the circumstances and environment which the researcher is exploring. Qualitative research is weakest when prior theories are unchallenged by the researcher and the exercise becomes that of validating a hypothesis which the researcher favours. Most important when conducting qualitative research is the ability to respond to unforeseen opportunities which present themselves. Whilst this may in some part be due to luck or 'being in the right place at the right time', by its very nature qualitative research offers the important depth of investigation which enables such fortuitous discoveries. Such factors occur when the researcher can spend time with those providing the data on the subject being investigated and tailor the scope of the research to the early results. Consequently, such data can enrich a researcher's understanding of quantitative data.

As this research is attempting to understand how a process operates from a new perspective of Business Process Reengineering (BPR), it is acknowledged that there is little conceptual and theoretical work to draw upon. Eisenhardt (1989) states

> 'when little is known about a phenomenon....theory building from case study research is particularly appropriate because theory building from case studies does not rely on previous literature or prior empirical evidence...(this) is most appropriate in the early stages on a topic' (Eisenhardt, 1989, p548)

As the research question at the centre of this particular study concerns the detailed understanding of the cognitive processes which occur in decision making on a construction project, the use of the case study is particularly suitable. The environment of a construction project forms a distinct microcosm which can be studied in isolation. Thus when carrying out initial research into a new area, the use of a case study approach is well justified. As Yin (1988) states

> 'In general, case studies are the preferred strategy when "how" or "why" questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real life context. Such "explanatory" case studies also can be complemented by two other types - "exploratory" and "descriptive" case studies'. (Yin, 1988, p.13)

There is a degree of scepticism over the use of case studies by some commentators. Much of the criticism is centred on the lack of rigour in the way in which results from researchers are handled, allowing equivocal evidence or biased views and interpretations to influence the direction of the findings and conclusions. Although not unique to case study research, these problems are easily identified and have tainted the view of this form of research.

A second area of concern is that case studies provide little basis for scientific generalisation. This criticism is not easily answered, but as Yin points out, is a criticism which can be levelled at many other forms of research, particularly experiments. The answer is that case studies are able to be generalised to theoretical propositions, but not to statistical generalisations for populations or universes. Yin considers this point to be crucial to the validity of case study work. Many examples can be given where the detailed understanding of a particular case can lead to a general understanding of how all similar cases would behave. An example would be disaster management where the study of reactions to a particular event, say the Clapham rail disaster, King Cross fire or the recent Channel Tunnel fire, does lead to an understanding of how people and organisations would behave in similar circumstances. This information is vital in ensuring that planning for such terrible events allows for human reactions to extremely upsetting and potentially disorientating situations. From this viewpoint it should be the goal of an investigator to aim for analytical generalisation where specific results from one case can be applied to a wider population with accepted variation within definable limits, and not statistical generalisation where some form of statistical predicability can be extrapolated for future similar events.

The third complaint is that the results of case studies are massive documents which are unwieldy, confusing, and fail to be concise. This need not be the case and the investigator should constantly strive to filter the data so that, when writing up, the key points are clear and are set within a context which adds understanding without rambling explanations.

Given the reputation that case study research has gained, it is important to distinguish the modern view of case studies from those of earlier products of recent history. Rather than focus on the subject matter in which case studies are used, a technical definition of a case study is

'*....an empirical inquiry that:*
- investigates a contemporary phenomenon within a real-life context; when
- the boundaries between phenomenon and context are not clearly evident; and in which
- multiple sources of evidence are used'. (Yin, 1989, p.23)

Within case study research there exists the option of concentrating on a single case or using multiple case studies where comparison between the cases is of importance. The decision will depend upon four key factors. These are:

- what questions to study
- what data are relevant
- what data to collect
- how to analyse the results

The issues of concern which have been identified in the literature review are all related to the way in which project players influence the outcome of a project. From the way in which the design is created and communicated through to the strategic level of review and change prescribed by Business Process Re-engineering, the focus must be on the information flows and decisions made which have such fundamental influences on the outcome. The implicit question would then appear to be an exploratory one, namely what are the factors which influence the information flows and decisions made in the dynamic and uncertain environment of the project.

Choosing a 'live' construction project provides the only reasonable source of the data necessary. Consideration has to be given to the criteria for the type of project to be studied so that an *analytical generalisation* can be made from any results. Once a project has been identified there begins the complex task of obtaining the correct data, both in terms of quality and quantity, which is required for subsequent analyses to be made.

The data gathered has to be capable of subsequent analysis and this factor necessitates the use of data gathering methods which go beyond simply retelling an interesting situation, an acknowledged trap into which many case studies fall. Indeed the Glaxo case study, which appears in the last chapter, is an example of this partial analysis. Although rich in data, the conclusions are formed primarily from intuitive opinions of the case. At the time of investigation this was valid as the case forms part of the background to the current study, both in terms of subject matter and research methodology. It would, however, be unacceptable to simply deduce results from the narrative and present these as rigorous analyses capable of either analytical generalisations or validation.

To the researcher interested in gathering qualitative information which can be more rigorously analysed, the choice of research methodologies becomes limited. The use of a questionnaire based survey was considered and discounted. The reasons are the limited ability to extract the detailed information required in such an exploratory situation and the inherent danger of bias in the choice of questions, their order, and the way the questions are phrased. There is little scope for the respondent to be able to express complex opinions and subjective information. More suited to this form of research is the use of interviews, where questions are placed before a respondent and answers recorded. The choice of structured or unstructured interview is made according to the direct comparability of the interviewees and the subject matter. In the heterogeneous environments found on complex construction projects, structured interviews would pose the serious problem of restricting the respondent to answering the set question and possibly limiting the full answer or leaving key points unexplored. The semi-structured interview is often regarded as being the best of the interview techniques for this form of research. Here an agenda of key points is decided upon by the interviewer in advance of the interview. During the interview open ended questions are posed which are phrased in such a way that the respondent has to explain rather than agree or disagree with a statement. The freedom of a semi-structured interview allows for unexpected information to be explored with the reassurance that the pre-set agenda of question areas will be covered. This very freedom, however, forces a greater responsibility on the researcher to understand the matters being raised and be able to incorporate the new data into the existing research framework. The unstructured interview can be combined in conjunction with semi-structured interviews, normally in the early stages of the data gathering exercise or where new areas of enquiry are necessary following unexpected preliminary results. Unstructured interviews can be used to gain a background to the current set of circumstances and for provisional data gathering. Information from such free flowing discussions can be then used to establish what areas need to be explored in greater detail and who are the best people to contact. The combination of unstructured and semi-structured interviews was the method of data gathering used on the Glaxo case study.

6.3 The context of a modern construction project

A modern and complex construction project has a number of important distinctions from other comparable sectors of project management. The key distinctions are related to the potentially powerful position of the client and the number of intra-organisational personnel who have to work on the development of a project. These considerations, together with the cost and the impact on the environment and community in which the project are located, form a unique project management situation. To place a construction project in its context, the management of a project can be represented as a map showing the key factors involved, as shown in figure 6.1.

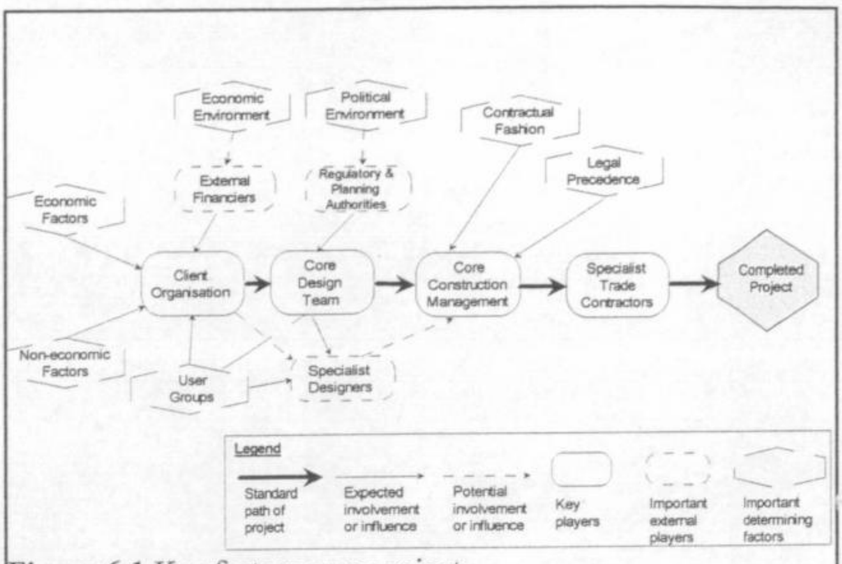


Figure 6.1 Key factors on a project

If the same presentational style is used to investigate other factors, one can start to develop a more comprehensive understanding of how a construction project operates. The functional elements of a project introduce a new level of detail to the map as displayed in figures 6.2a, 6.2b, and 6.2c. Within each of the project player organisations there will be a range of functions operating, either consecutively or concurrently, which will have varying influences on the outcome of the project.

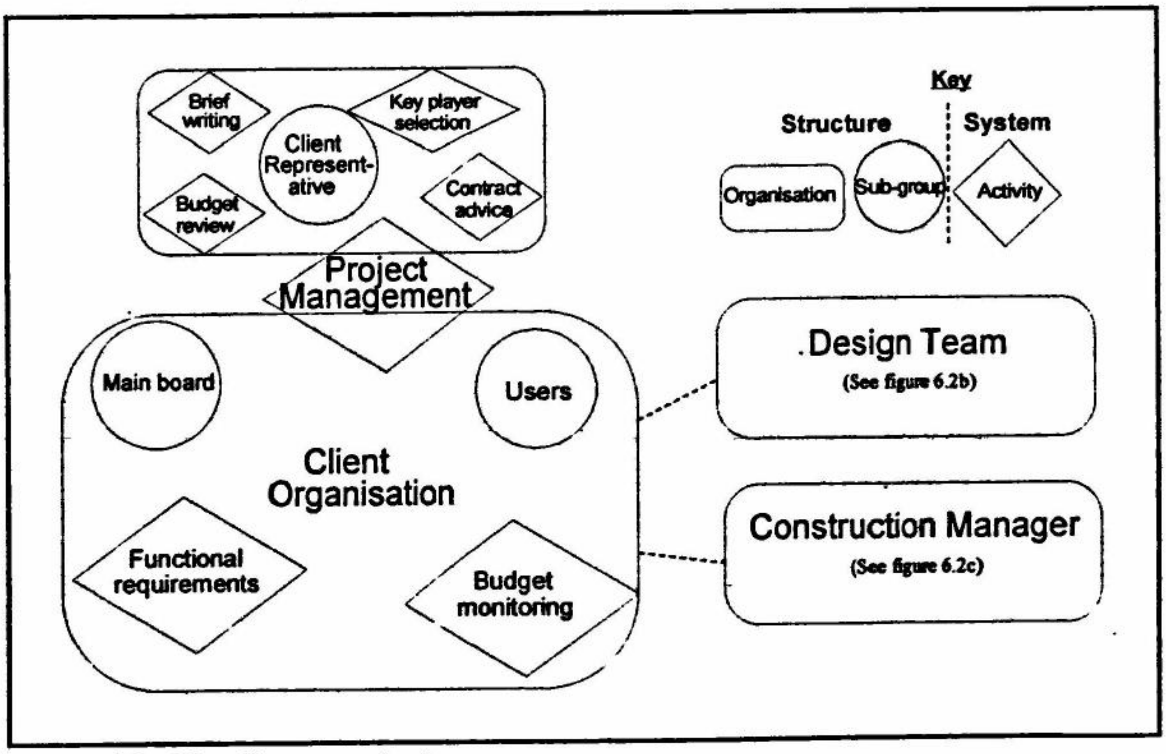


Figure 6.2a The client organisation map

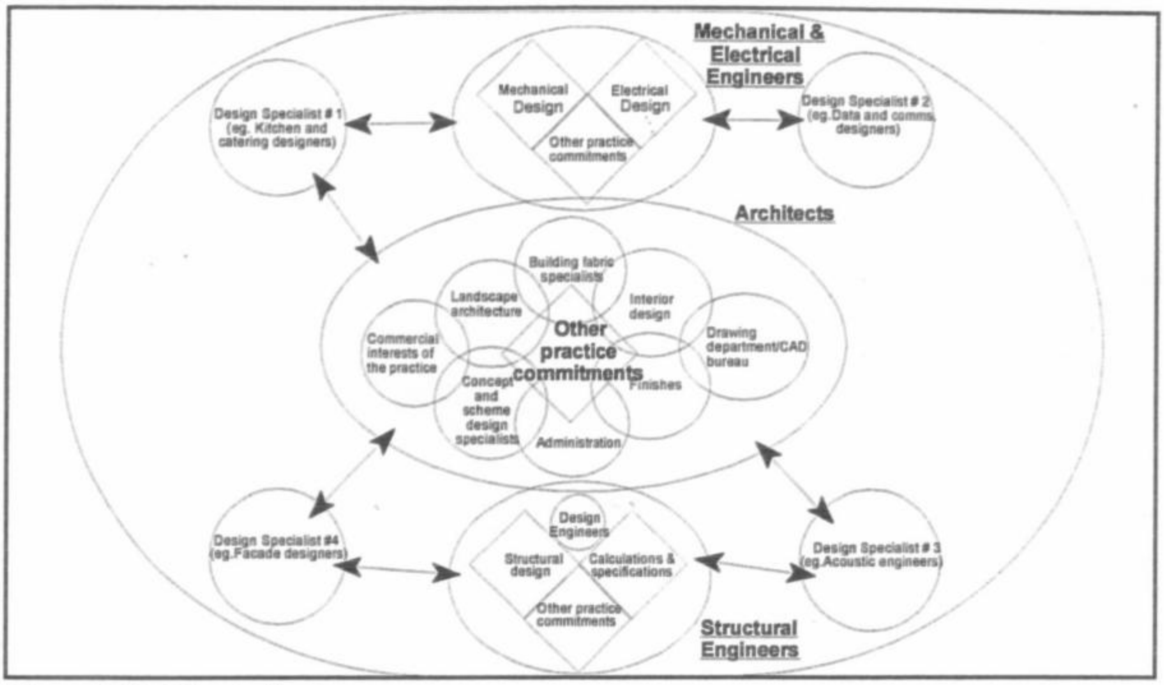


Figure 6.2b The design team map

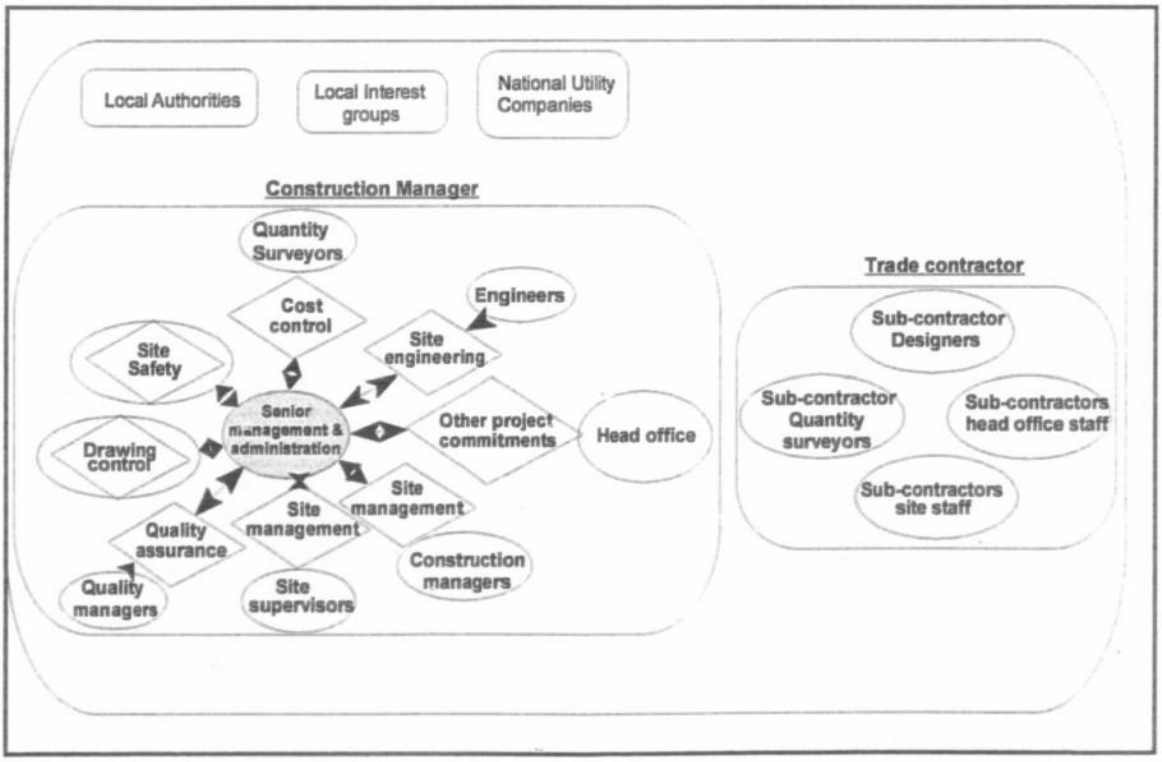


Figure 6.2c The construction manager map

The diagrams above represent the functional detail which can normally be expected to be found on large, complex projects. Yet although there is much detail as to which functions are present and where the links between these functions may be, there is little information on the processes which are in operation. It is therefore difficult to understand how, for example, the key decisions or the information base, are developed. In order to gain this important understanding it is necessary to discard the functional map and consider the process map. From the Business Process Reengineering literature it is clear that what is important is the careful scrutiny of value adding stages of development and how the various stages link together to provide a unified process. Thus, in the construction case, key elements of a construction project become the actual elements of the building. These are, for example, the roof, structure and mechanical and electrical services.

By breaking a construction project down into its basic constituents and examining how these are developed from vague ideas and desires, through to completed parts of the building, a more incisive insight can be made which allows external parties to comprehend the complexity and provides the actors involved in project management with an understanding of the management issues which need to be addressed.

6.4 A methodology for design management research

The apparent gap in the knowledge base related to the actual process operating during the design stage of a construction project is the focus of this research. To explore this area, three further in-depth case studies were undertaken which addressed the key information flows and decision making processes involved in the design of the façade, one of the major elements of the project. By applying the principles of generalised analysability, it is hoped that the study of one element of the project's design will be representational of the wider process.

After careful consideration of the possible elements of a construction project which were suitable for study, it was decided that the building's façade provided the best example for three reasons. The key considerations in making this choice were firstly, that the element of the project studied must be of importance to the overall project and provide a reasonable example of typically complex design management and information flow. Secondly, its design must be influenced by a number of factors, requiring the involvement of various parties. Thirdly, there must be a degree of commonality about the element between highly heterogeneous projects. As the façade provides the public with their first impression of a building it is reasonable to assume that both the client and the architect (for this element the architect will be assumed to be the lead consultant) would have important views on its design. As the cladding of a building becomes more technically demanding and inevitably more expensive, there is the increasing use of specialist consultants who assist in the design of the façade. The façade also requires engineering input as the aesthetic design requirements have to be integrated with the limitations imposed by the structure and have to withstand a range of external forces. The construction programme and concerns over buildability will involve the construction manager. Finally, on an increasing basis, modern façade and construction techniques require the design input of specialist manufacturers and installers.

Thus, the development of the façade provides a complex picture of the more general design processes found on modern construction projects. To rigorously research this area a methodology was needed which is capable of dealing with complex data. As the information flows and decision taking were not directly quantifiable, and the research was necessarily limited to a small number of cases, traditional statistical methods were not applicable. Equally the qualitative nature of the data would not have been easily analysed if the data were purely generated from interviews, either structured or otherwise. The reason for this was that by definition, in an interview environment, the interviewee is a *respondent* to the interviewer's questions. This can lead to both omission and bias in the results. As the research was of an exploratory nature, considering how individuals make a process operate, the objective of the research was to establish the primary factors involved without prior assumption. In this context the research was focusing on systems modelling as understood from analysis of the cognitive processes employed by the key decision makers.

6.5 Cognitive Processes

One of the most important aspects of the data gathering exercise for this research was to use a methodological tool which could capture the cognitive process in an organisational environment. This area of research is dominated by the pioneering work of George Kelly and his Theory of Personal Constructs (Kelly, 1955/1963). The essence of Kelly's theory is that man is continually striving to "make sense of his world". It is built around a single "fundamental postulate" and eleven corollaries which explain that postulate. The fundamental postulate states:

> 'A person's processes are psychologically channelized by the ways in which he anticipates events'. (Kelly, 1963, p.46)

The postulate implies that a person continually checks the sense he/she makes of his/her world by using it to anticipate. The basis for this viewpoint is a number of basic themes which form a *construct system*. The theory allowed for three types of corollary, individual, sociality, and commonality, which are all used by individuals to form construct systems from which the future is expected. The variation in construct systems used by individuals explains the difference in expectations and perceptions found in life. For example, effective interaction between members of a problem solving team depends upon the extent to which they can understand how the others interpret the situation.

Within the developing world of operational research the work initiated by Kelly was continued and translated into a practical research tool capable of assisting operational researchers to understand organisations, systems, and business problems. From this work developed Repertory Grids which have been used extensively by both academic researchers and business consultants to investigate the complex psychological aspects of business systems and problem solving. Repertory Grids were devised to help elicit the system of constructs that a person uses to make sense of a repertoire of elements in a situation. By seeking to detect the psychological attributes that identify similarities and contrasts between elements the constructs would be revealed. Once identified, the problem owner or subject of the analysis would be asked to show how the constructs were linked and the results could be analysed statistically to identify the system of constructs and elements used to describe the situation under investigation.

Although well established as a useful tool in the understanding of how people and systems operate, there became an increasing awareness by those involved in operational research that repertory grids were limited in their use. Eden (1988) describes how the use of repertory grids became problematical in complex problem solving environments and that the requirement to formalise linkages between corollaries was not ideal. The statistical analysis which was employed to analyse the grids often resulted in information that was of little use to consultants and the problem owners. This applied to both the straightforward statistical analysis such as simple linkage clustering as well as the more complex 'principal component analysis'. However, the most relevant criticism of repertory grids is that...

> '...a grid is constraining in the degree of richness that can be captured - a grid much larger than 12 x 12 becomes unwieldy to elicit and even more confusing to analyse - and yet a single client will talk about a problem with more richness than could ever be captured by such a grid. A client team will generate ideas, explanations, and ways of making sense of the situation that will certainly run into several hundred constructs.' (Eden, 1988, p.3)

This criticism of repertory grids led to the development of an approach which allowed for more complexity and which fully captured the cognitive processes being operated by those being studied. Working on Kelly's Personal Construct theory, Cognitive Mapping was developed as a way of graphically representing the understanding of individual's surroundings and worlds. As a technique it has been used since the late 1960s and has been used to understand how people learn, how they remember their spatial location and, increasingly, how politicians and those in business make decisions.

The recent developments in cognitive mapping and, in particular, the use of powerful analytical computer software, has introduced the possibility of studying extremely complex environments with a degree of objectivity previously unobtainable. The research tool which was therefore proposed for studying the design process on complex construction projects is Cognitive Mapping.

6.6 Cognitive Mapping

The theory argues that human beings are continually striving to 'make sense' of their world in order to 'manage and control' that world. Implicit in this theory is the individual as a problem finder problem solver, using concepts rather than emotion to guide action. Early applications of cognitive mapping were developed to address the psychologist's need to explore how people understand their spatial environment. Although the following quote is taken from an early text, it indicates how cognitive mapping had the potential for wider application.

> '*Cognitive mapping* is an abstraction covering those cognitive or mental abilities that enable us to collect, organise, store, recall, and manipulate information about the spatial environment....Above all, cognitive mapping refers to a process of doing: it is an *activity* that we engage in rather than an object we have. It is the way in which we come to grips with and comprehend the world around us'. (Downs & Stea, 1977)

A definition written from a general viewpoint is that a cognitive map provides:

> ...a model of the 'system of concepts' used by a client to communicate the nature of a problem. The model represents the *meaning* of a concept by its relationship to the other concepts. (Eden, 1989)

Cognitive mapping has developed into a research tool which has been applied to decision making. Brown (1992) demonstrates its wide spread application to the study of business strategy in the crop protection industry. This study used cognitive mapping as one of the data gathering tools in a comparative study. The results were encouraging and, with the use of specialist software (Graphics Cope), the data were capable of rigorous analysis.

The application of cognitive mapping to the business world has focused on strategic problem identification and solving. The University of Strathclyde is a leading centre in this area and has produced much consultative research. The University's Department of Management Science has been extensively involved in the continuing development of a practical methodology for problem solving in businesses, resulting in Strategic Options Development and Analysis (SODA) and the continuing development of software capable of handling cognitive maps.

In justifying the use of cognitive mapping, Brown considers various categories which are important factors in gathering data. These categories are: truthfulness, value-tapping capacity, richness, reliability, data quality, amenability to analysis, large scale suitability, training requirement, ease of use, tedium inducement, esteem threat, ethical acceptability, client usefulness, and dependence on investigator skills.

Although written from a primarily psychological perspective, the analysis suggests manual mapping using straightforward visual techniques where the respondent can be directly responsible for generating the map (on large flip chart paper) prompted by the interviewer's questioning, adopting the style of a persistently curious child. One of the most significant benefits is that the threat created by gathering the sought information is much reduced when compared with other methods.

> 'What is done is visible to the client at all times and the true essence of the client's wisdom is being recorded for posterity by a willing acolyte - all very gratifying'. (Brown 1992).

The thoroughness with which cognitive maps are created is crucial for future analysis. To understand fully the way in which individuals operate, and especially when aggregating to form summary maps, the context of utterances is important. It is therefore the responsibility of the interviewer to record as much information as possible regarding the construction of the map. This is done without directing the response of the interviewee.

6.7 Using Cognitive Maps

The generation of a cognitive map firstly requires the researcher to comprehend the issues involved in the problem. This understanding is required so that the interview with those involved with the problem can be prompted to identify *their perceptions of the problem.* A cognitive map can be constructed in two directions. Firstly it can be commenced with the identification of the goal or concept which is perceived by the problem owners as the key problem to be addressed. This goal is explored further and then gradually worked down the map towards the increasingly detailed options to achieve the goals. Alternatively, one can start from the detailed options and gradually work up the map towards the goals by exploring each concept in turn as a potential option. The choice is made by the researcher based on the type of problem, the process involved, and the attitudes of the client.

A major advantage to the use of cognitive mapping is the way in which the maps are produced with the client. Although maps may be constructed from documentary evidence, there are benefits gained through the map being generated in conjunction with the client. An important reason is the map is 'owned' by the client from the outset and the client can witness its development and modification. All subsequent analysis by the researcher takes place on an accurate reflection of the client's view of the problem.

The importance of cognitive mapping becomes more evident when the problem owner is a group (normally a small group) and not an individual. In the modern business world this sharing of problems and responsibilities is commonplace and gives rise to the increasing problem of group decision making. Cognitive mapping is used in this context to explore all the individual's perceptions and then to merge these maps to give a group map. This is a powerful tool in the understanding of the problem by the group concerned. By developing individual maps considerably more 'air time' is given to all the individuals concerned than would normally be expected in meetings. As members of a group would normally be expected to contribute differing views to any problem, the maps generated will also vary. Once the individual maps are completed they are analysed by the researcher to find areas of commonality. To an extent this analysis relies on the researcher understanding the problem so that variations in language used by the group members can be compared and linked. The production of a group cognitive map can be an onerous task according to the factors involved in the specific case. It is not uncommon for the group cognitive map to have many hundreds, or possibly thousands, of inter-related concepts and goals. It is to deal with this complexity that specific software has been developed.

In the area of research into the construction industry, little work has been carried out which records the use of cognitive mapping. The only recorded use of a mapping approach has been carried out by Brightman *et al* (1996) but this work uses the computer package developed for creating and analysirg cognitive maps as a graphical database containing more factual information, which is not any one person's cognition. The aim of the research is to establish a tool which those in the construction industry can use to help facilitate strategic decision making. The research began exploring how this work could be carried out and has, at present, developed models which can be used by building contractors. Once the framework and rules for creating the factual database is established, the principle of model generation would be capable of being expanded to all sectors of the construction industry, or indeed many other industries.

6.8 Application of Cognitive Mapping to the Research

The research, as previously stated, focuses on applying the concepts of Business Process Reengineering (BPR) to the project based design management. The key to this research question, as proposed by the BPR advocates, is to fully understand the system as currently operated and to then consider from a tactical perspective what the value adding aspects of the process are and to re-model the system to produce these.

In this context, cognitive mapping is a tool to be used to gather the information on how the current system operates. Individual maps were created, analysed, compared and summary maps for the project produced.

6.9 Establishing the initial approval

As the façade is a common feature on all projects, the range of projects is not limited. Choice limitations do exist as to the degree of complexity found on the project and the involvement of leading corporate players rather than individuals. The expected size of the project would therefore be predicted to be in a minimum price range of £10-20 million, and would involve major players in the industry. The choice set would not necessarily favour projects where the façade is the single most important element, although such a project would be valuable to study. The actual choice was limited by the number of available projects which grant permission to study.

It was recognised that the research into real project situations was always likely to lead to a degree of hesitancy from those involved particularly, as by its very nature, the information given by the interviewees would be a personal perception of how they understood the situation or process, which could be to reflect in a negative way upon their coalition colleagues. The possibility of this arising on any of the case studies could not be completely eliminated, however it can be substantially reduced. The principal considerations which would negate this factor concern the approach taken both to gaining entry to study the project and in dealing with the individuals from whom research data is collected.

A contact for a construction project would probably not be the most senior client representative, however it is necessary to be able to gain access to this person, either personally, or through representation to one of his or her close colleagues. It was found on the case studies that early contact with a very senior representative from the client organisation proved invaluable later on. Firstly, this contact was important because it established the researcher's credentials, motives, and anticipated impact on the project. Secondly, it allowed the client to provide key background data on the corporate rationale for aspects of the project. These important objectives and constraints are often poorly considered by the other members of the project coalition and, therefore, this source of data can prove to be highly revealing. Finally, and arguably most importantly, the involvement and support of the client organisation allows far easier access to other members of the project coalition than could otherwise be expected.

On each of the case study projects, the research was brought to the attention of the senior client representative and access to the project was approved. On the Glaxo project the size of the coalition and client organisation meant that more substantial contact was made with the Glaxo staff below the project Director, Michael Herriot. However, the approval and assistance provided by the head of engineering from Glaxo demonstrated to all concerned that the client organisation actively supported the research. On the Harlow case study, the largest and most complex of the subsequent case studies, the senior client representative Dr. John Cooper, provided much useful information, as well as requesting that all other parties to the project assist in the research if, and when, requested. On the Boots project, John Barks, the senior project manager from Boots Central Engineering, provided great assistance and gave a detailed account of the background to the project. Finally David Low, Property Director for London & Manchester Assurance, was happy for research to be conducted into the unusual and innovative design for a rare, speculatively built development in London in the mid 1990s.

6.10 Establishing the field research parameters

The nature of the research, involving, as it did, the development of the design of the façade through the many stages between inception and completion, suggested that the research follow this chronological lead. The sequence of data gathering therefore followed as closely as possible the order of involvement of the different personnel from the various organisations involved. As the research records the perception of the process from each individual, it was not possible, in advance of commencing the data gathering, to determine exactly who would needed to be interviewed. Whilst it is obvious that certain title holders would need to be contacted, that list was not exhaustive. Rather, the research followed a path dictated by the guidance from the interviewee. Thus the first interviewee, or contact for the project, indicated the key personnel and advised as to the order. For the façade the important stages were to establish if the client had a strong idea as to the facade's aesthetics or functional performance before discussions with the concept architect or master planner took place. The sequence was then dictated by the advice of the first interviewee, tempered by any access to those involved. An organogram for a project showing the prime information channels might therefore be as shown in figure 6.3.

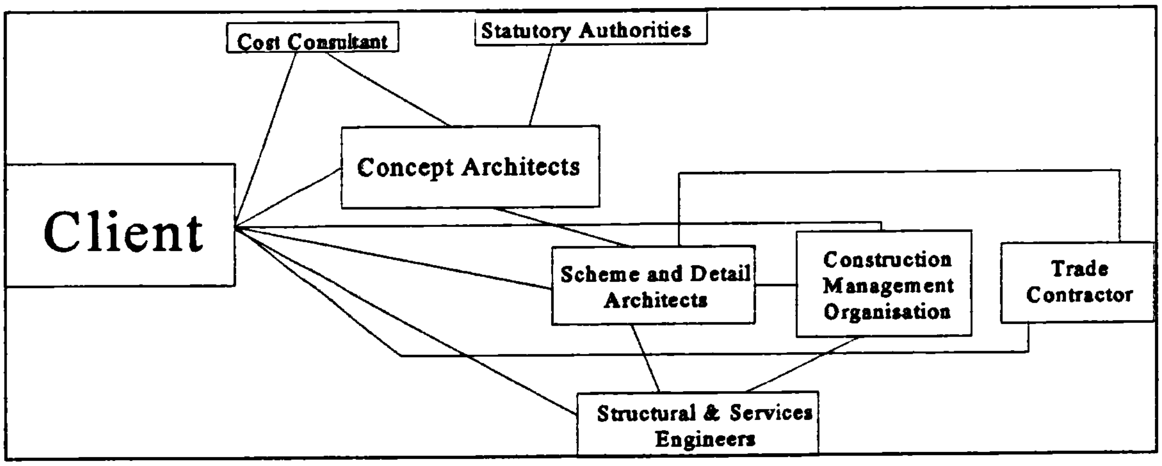


Figure 6.3 Typical project organogram

Those individuals actually involved in developing the design probably liaised with their counterparts from other coalition organisations in a variety of ways, from contractual documents through to face-to-face meetings. As each individual project developed, so the large number of variables affecting the type of information exchange, and its quantity, alter the design management outcome.

6.11 Gathering the data

The theory on which cognitive mapping is based clearly requires that the researcher captures the full richness of the interviewee's perceptions relating to the subject under investigation. The most effective, and rigorous, method for capturing the data is to therefore map directly in the presence of the interviewee. This achieves all the benefits outlined in the previous sections, of ownership, clarity of understanding and direct validation of the map by the interviewee. The problem with this direct approach is that the researcher is required to have considerable prior experience of mapping, if the exercise is to be carried out without undue delay and consequent frustration. As the area of the research is complex and involves many sub-areas, it was deemed impractical, given the level of expertise and experience of mapping by the author, to create maps directly during the interview. When dealing with such complexity an alternative, and recognised, method for data gathering is to use semi-structured interviews and a method of recording the information which captures the true perception. The most effective tool to use therefore is a tape recorder, together with hand written notes. The researcher should be able to articulate clearly the scope of the area of enquiry and be able to start the interviewee at a logical start point. After that the interview direction will be guided by the combination of development of explanations of ideas from the interviewee together with prompting, where necessary, from the researcher. The researcher must ensure that all aspects of the area of enquiry are covered during the course of the interview and that all issues are explored thoroughly, but should not force the interviewee into areas which the interviewee feels are irrelevant. The result of the interview, the primary data, would therefore consist of a transcribed set of interview notes. These notes form the basis of the cognitive map which is formed by dissecting the notes into discrete statements, *the concepts*, and then coding, or linking, them to form a cognitive map. This was the chosen method, which worked extremely well, with only one interviewee declining the use of a tape recorder. The disadvantage of the loss of direct ownership of an individual map created in the presence of the interviewee is an acknowledged weakness of the subsequent maps, indeed raising questions of how the maps were coded (linked). However, given the subject area and the exploratory nature of the research it was felt justifiable that the maps were created indirectly as the disadvantages of loss of direct ownership were less than the advantages of allowing an uninterrupted flow of rich data. The actual interviews, conducted with managers and designers who were actively involved on projects at the time, took in all cases, longer than initially intended, even as experience anticipated longer time spans for interviews. In all cases the interviewee was willing to go into great detail about areas of interest or concern which led to some long interviews, the longest being just under seven hours! The average duration was just over two hours, of which some time was spent explaining what was required. Text notes were taken both to back up the tape recording as well as to ensure that any side tracks were returned from to continue the full description.

6.12 Processing the data

The constructing of an individual cognitive map from the transcribed interview notes requires a degree of interpretation from the researcher. Starting from the beginning of the notes, the map is built on the virtual sheet within the computer software. As the concepts are coded (linked) they start to form an explanatory track for elements within the general area of enquiry. Where there are distinct breaks in the explanation, then the cognitive map will start a new track. Interpreting the data as it entered allows the researcher to link concepts which were not necessarily explicitly stated. Clearly there is a risk of mis-interpretation or error in this stage, which requires both care from the researcher, and necessitates the need for validation from the interviewee. The important issue of validation is discussed in greater detail later in this chapter. Figure 6.4 (in separate pocket, attached) is an example of a basic cognitive map. Due to volume of information contained within such a map, the reproduction of the map in figure 6.4 is produced on a large sheet. The sheer complexity of the maps is evident from figure 6.4 and the validation became problematical.

6.13 Validation of data

A number of methods for validation were tried. Starting with the submittal of the original cognitive map, which was largely unsuccessful, due to the obvious complexity a number of alternatives were tried. The final choice was the submittal of a far more refined map, together with the separated maps of the individual clusters. Given the busy nature of the personnel interviewed, the approval gained was probably based on a casual perusal, but as it was likely to take a great deal of time to fully examine the results, this was largely expected. This issue would be less important if the maps were created directly in conjunction with the interviewee and is an important point for future research. The case description was also sent back to the senior client's representative for factual checking, which was gained without significant alteration.

Before this validation took place there were a number of analytical tools available in the software which enable a check for errors to take place. Loop analysis detects any circular arguments entered. These can be studied to check whether they are errors or whether they accurately reflect the situation as described. A list of the *head* and *tail* concepts provides information on all the ultimate explanations and starting points respectively. The starting points for a track would be expected to be *the de facto* position from where other developments occurred. These would tend to be statements of fact and not opinion. Conversely, *head* concepts form the final situation or opinion of a course of events. There should not be any justification for linking them on to any other concepts. By reviewing the results of this preliminary analysis, the integrity of the cognitive map can be checked prior to submission back to the interviewee.

6.14 Cognitive Mapping Software

Graphics Cope has been developed as a non prescriptive, analytical database which can be used for direct map drawing. Using the Windows Graphical User Interface as a base Graphics Cope allows concepts and links to be entered anywhere on the virtual surface of the VDU. The software is more than just a substitute for a blackboard, as it contains various analytical tools for the study of the maps.

When faced with group maps which contain many concepts and linkages, the ability of the human brain to identify patterns and clusters becomes limited. The software uses a fourth generation language together with complex algorithms and heuristics to identify main concepts and clusters of related concepts. Complex and large maps can be condensed down using these identifications to present main concepts and clusters grouped under appropriate headings which can then be the basis for further discussion with the group. The ability to review different aspects of the same map without losing the individual's contribution makes the software a powerful tool. Although Graphics Cope is designed so that it can be used on site in direct consultation, there can be just as much gained through the manual recording of the map on large pieces of paper or a board, the final version of which, after all modifications and discussion, can be transcribed onto the computer.

Once the individual maps have been recorded on the computer the analytical functions of Graphics Cope become the key to the analysis. Individual maps can be analysed in a number of ways, providing the researcher with a range of possible interpretations. The software is capable of being programmed as a form of expert system to look for particular linkages which may be found commonly. Using skill and experience, the researcher is then able to aggregate the individual maps and record a group map based on the gathered primary data.

Ideally the computer version of the group map needs to be taken to any further feedback or workshop sessions so that the various views and analytical tools can be applied to this far more complex view of the problem(s) involved. The ability to print a number of different views is important in reviewing the possible actions which can be taken. This flexibility can be an important factor when used in the course of discussions.

6.15 The use of Cognitive Maps as part of the current research

The intention of this research was to seek to understand the key processes that occur as part of the management of a modern complex construction project. As such it dealt with the 'soft' issues involved in project management which are increasingly being seen as the most significant parts of project management (Morris 1994). This area has received little previous attention, with the majority of academic work being focused on the control of programme, cost and, most recently, quality.

Within this context, the research focuses on the processes involved in bringing an important element of the building from the early stages involved with conceptual ideas, through detailed design, with associated cost and programme issues, to construction. This concentration on 'upstream' events is justified in both theoretical terms as well as from a practical viewpoint. Theoretically it is acknowledged that significant improvements can be gained from improving the robustness of the quality of information generated at these early stages. Practically, the time available for research limits the study to a portion of a project's life cycle, requiring clear breakpoints to be established.

In order to carry out the proposal, suitable projects were identified and a common element of the building selected. The key players involved in developing the design, budget cost and programme were interviewed as and where necessary and the results expressed as cognitive maps. For each project studied there was therefore substantive evidence on the process involved in the development and management of the façade of the project. The principles of BPR were then applied to see if the actual approach can be modified to provide a process for the strategic management of the design, which is more effective.

As a project involves many disparate views it was expected that the cognitive maps recorded from the individuals concerned would be complex and divergent. The compilation of these maps to form a project map required the use of computer software capable of handling such quantities of data. Without Graphics Cope the analysis of the data would be both inaccurate and partial and little of value would be learnt. With the software, the analysis was capable of being reviewed by those originally interviewed and their comments considered. It is to be stressed that the construction industry is notorious for disregarding well intentioned advice if it feels that it cannot be incorporated without the need for major re-configuration.

This research is therefore aimed at providing two extremely useful recommendations. Firstly, it will demonstrate how the important decisions and actions required as part of project management are actually taken and perceived by those involved on a construction project. This information is crucial for a better understanding of how a construction project is managed. In the light of the Latham Report, such information will be crucial if improvement in effectiveness and efficiency are to be sought for the long term. Secondly, by analysing actual projects involving leading industry players it was hoped that a more holistic understanding of the problems faced in developing a project would be made. Without such cross referencing, the existing approaches will continue to be made and improvements virtually impossible to achieve.

6.16 Analysing the cognitive maps

The basic cognitive map is of limited value *per se*. To unlock the data contained within, a number of steps are necessary which decompose the map, analyse the component parts and then reassemble the map to yield a new map. The following section details the order of the analysis commencing with the first stage following the building of the basic map.

Once the basic cognitive map has been initially checked, the analysis of the map can begin. Firstly, and critically, cluster analysis is used to break the basic map into a number of sections. The cluster analysis function within Graphics Cope searches the whole map for areas of strongly linked concepts. The identification of clusters is carried out impartially by the software using a complex algorithm which seeks to identify a core number of concepts (normally set at 30, as this is considered as being towards the upper end of the range for data interpretation) but which compares the number of links within the cluster to the number of links between the cluster and the rest of the map. The software program seeks to best satisfy the combination of objectives of the target number of concepts within a cluster with the minimum number of links between the cluster and the remainder of the map. Where necessary the software increases or reduces the number of concepts until the best solution is found. An example of the pattern of clusters for a typical cognitive map is given in figure 6.5. The colours used in figure 6.5 are only to indicate the cluster set location and are not related to the analysis of the cognitive map's contents.

The results of the cluster analysis are stored as 'sets' which are amenable to independent analysis. To commence the next stage of the analysis, each cluster is viewed and linking concepts are identified using a 'style'. Styles are user specified codings to enable an easier understanding of a map. The first style created is to allow the identification of bridging concepts. These concepts are the links between clusters. Some clusters may have no bridging concepts and consequently are isolated areas of the map. If a cluster is identified containing only one concept then this would normally be a mistake and would mean that a link has not been entered. This can easily be remedied and the new map subjected to cluster analysis again. The most clearly interpreted type of style uses colour as the primary way of

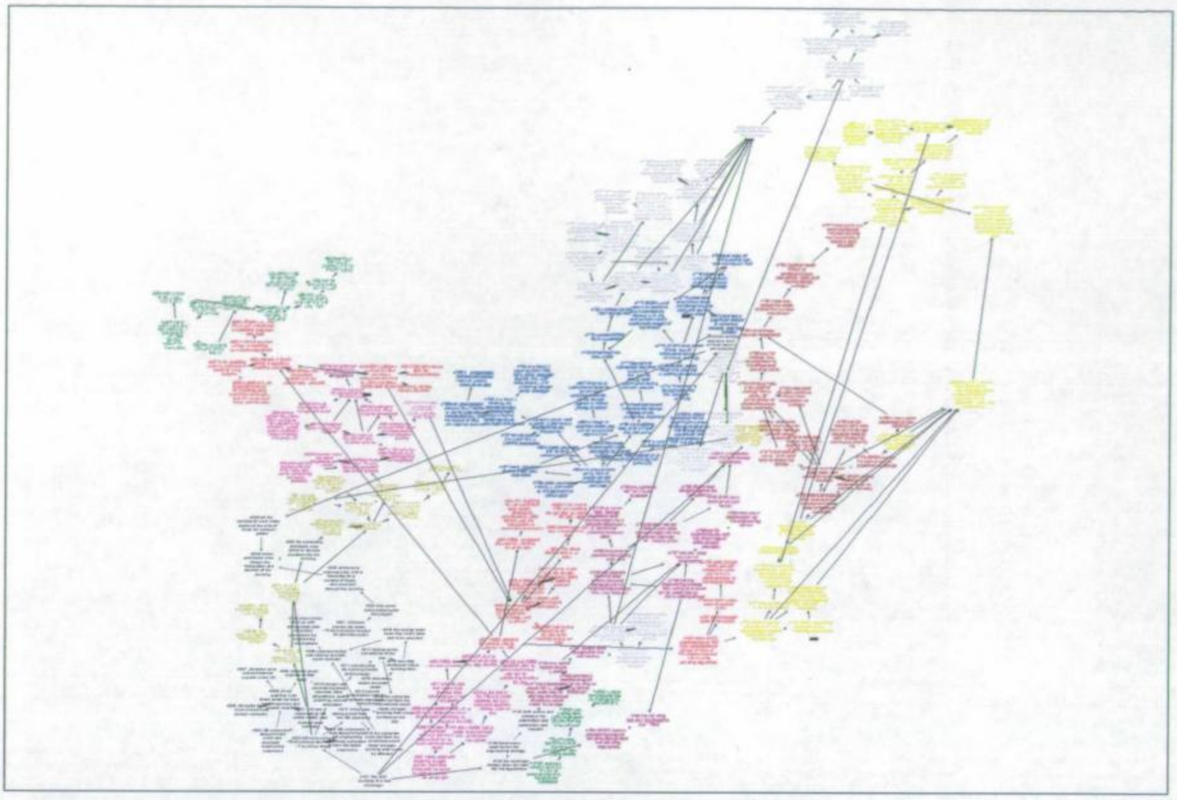


Figure 6.6 Colour coding for clusters within the cognitive maps

distinguishing concepts. Once bridging concepts have been identified and marked a note of the link is made using the memo card facility. This facility is an aid which allows any concept to store additional information. Once this stage is completed, each of the clusters are treated as a map in their right by using the 'zoom' facility. Once enabled a 'zoomed' cluster is effectively a map in its own right on which a number of analyses can take place.

The three main types of analyses used are central analysis, domain analysis, and the identification of head concepts. Central analysis considers each concept in relation to the rest of the map and gives it a score. Domain analysis considers the influence of each concept over the remainder of the map. Concepts from which a number of consequences derive would therefore be important. Head concepts are those concepts which act as the ultimate explanation for that line of argument. For both central and domain analysis, a preset number of the top scoring concepts were identified, normally being the top five scoring concepts from any cluster. This choice of the number of top scoring concepts (five) was derived after experimentation and was found that 5 30 gave the most important concepts. Increasing the number for these two types of analysis did not provide useful results, as the analysis lists the results in rank order with the most 'important' concept first and the least last. Five concepts from 30 were therefore found to provide the optimum results. The results of each form of analysis were identified as a style with the concepts colour coded. Thus figure 6.4 can be seen as representing concepts with different interpretations. Figure 6.6 is a legend for the colour coding.

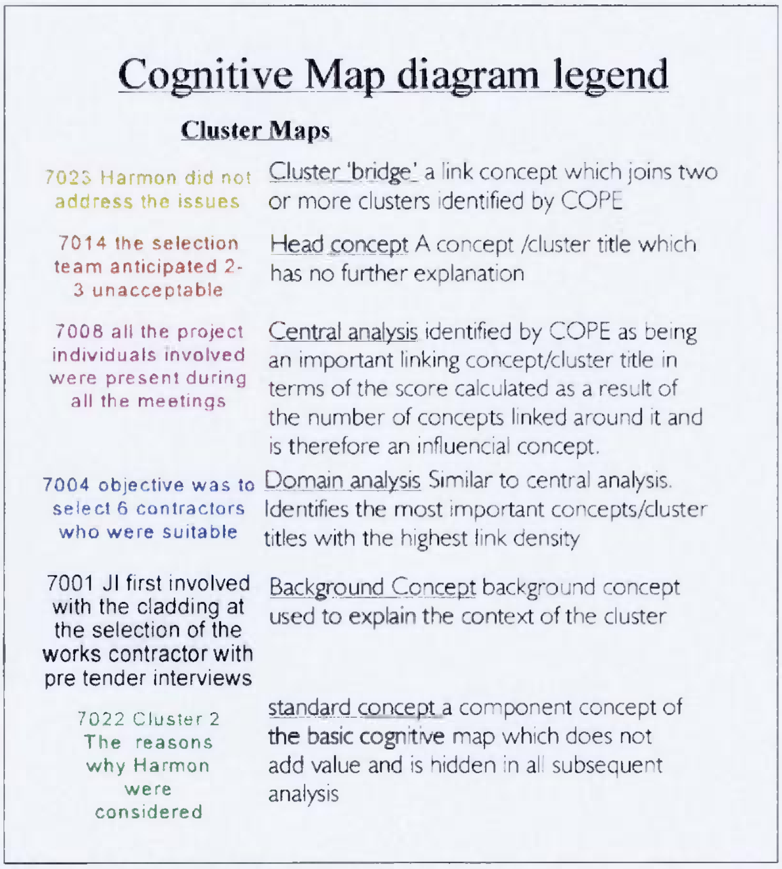


Figure 6.7 Legend for the cognitive maps

Having coded the concepts within each cluster, the selected concepts (all but the standard concepts) are added to a new set which is then mapped. The new set is then collapsed, which is where the software reinstates links between the concepts which may been omitted from the new set. The result of this stage is that the cluster is reduced to only those concepts which are important or which add explanation. This reduced cluster is then exported from the mapping software to a graphics software package where its presentation is enhanced. This stage, which is trivial to the overall research, is, because of compatibility problems, an extremely lengthy and labourious stage. During this stage the linking arrows to indicate the connection to other clusters are added, together with the concept number and cluster title. The title for the cluster was the derived from an intuitive inspection of the contents of the cluster. It was gratifying to find that in virtually all cases a title was easily created which fairly summed up the contents of the cluster.

6.17 Presenting the data

When constructing the overall map an important piece of information which the mapping software did not handle was the strength of the of links between clusters. This problem is created by the fact that, in the original clusters, there may be more than one link between concepts contained within each cluster. The number of links between clusters is an important piece of information, as the relationship between different clusters varied. To overcome this problem, the overall map, created in Graphics Cope, was again exported to a graphics program and the links were redrawn. Firstly, the loops, created by joining the clusters (by now reduced to their title) were made clear by the introduction of curved black lines, together with dashed coloured lines, to indicate the presence of loops. Secondly, the strength of the link between concepts was illustrated by using different line thicknesses - the thicker the black line linking the cluster titles, the greater the number of links between them. The difference between the map as produced by the mapping software and an enhanced map, incorporating printer requirements, is given in figures 6.7a and 6.7b.

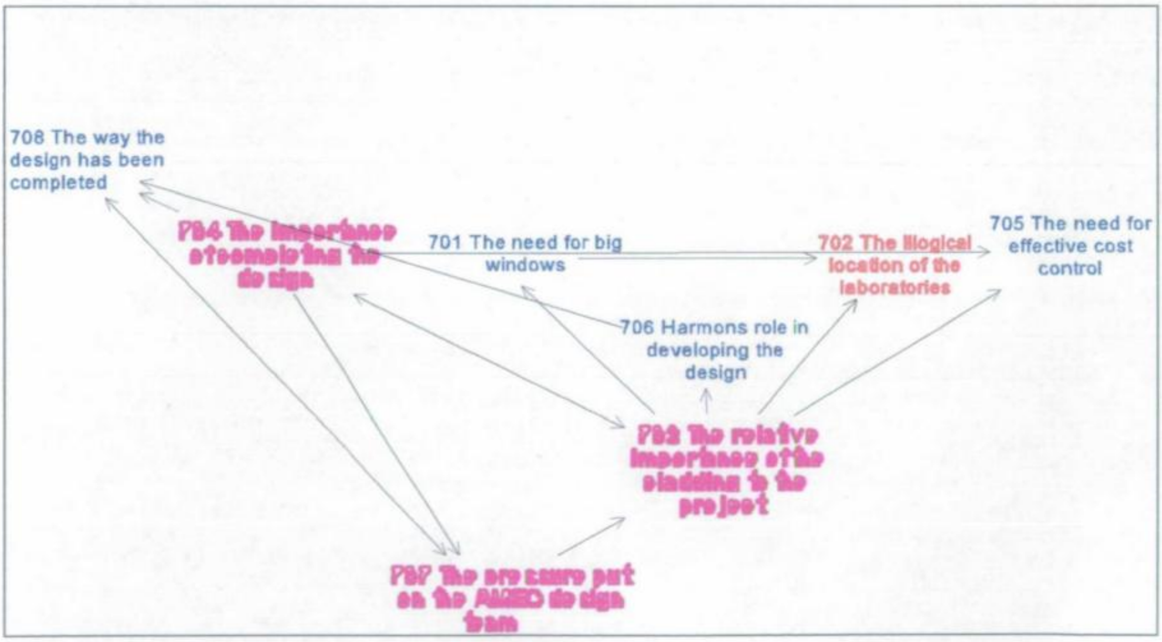


Figure 6.7a Example of map from Graphics Cope

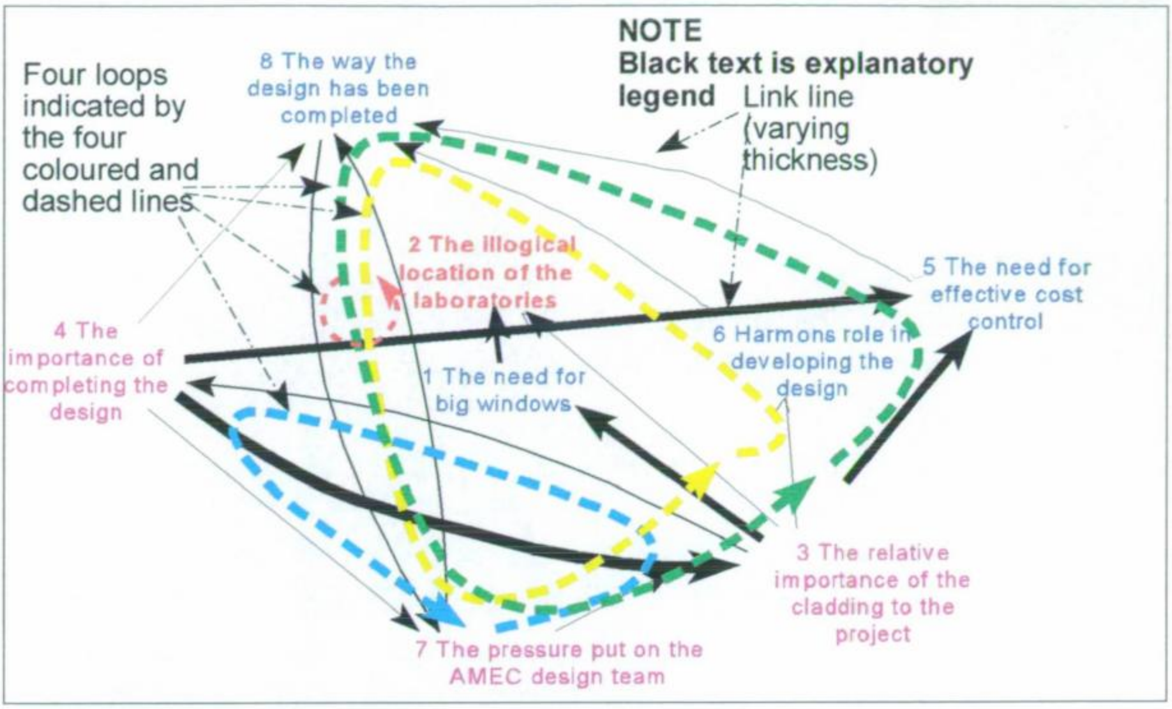


Figure 6.7b Graphically enhanced cognitive map

6.18 The final stage

Once the interviews were completed and all the overall 'summary maps' constructed, the final task of combining the maps began. This stage firstly required the careful examination of each of the cluster titles in each summary map. Where a cluster title was found which appeared to be similar to a concept in another individual's summary map further analysis was required. The object of the exercise was to establish those cluster titles which appeared in more than one individual's map. As the quality of the data reflected individual's phrasing and vocabulary, there was the distinct possibility that two statements may have the same meaning but not use the same wording. It was therefore essential that the researcher ensured that the meaning of the concept was at the centre of the comparison, using intellectual faculties as well as the software's capabilities. Where common concepts were found they were merged, thus providing a 'bridging point' between two individual maps. The careful examination of all the cognitive maps enabled the researcher to link cluster/concepts from one individual to another, following the logic derived from the knowledge of the project. This additional linking was only used where there was clear justification. Where there may have been any doubt as to whether the link was justified, it was not used.

The incorporation of all the individual maps into a combined map was the objective of the exercise. There was clearly a requirement to use interpretation at this stage, but as with the development of the original cognitive map, there is the facility to validate any possibly contentious combinations of concepts.

When merging, the software allows for the wording of either of the concepts to be used for the new merged concept, or for a new alternative. As a failsafe, both original text strings are stored 'behind' the concept for possible future use.

The possibly more contentious manipulation of the data is the linking of concepts which form the consequence and explanation of a situation, as explained by different individuals. This intervention by the researcher is considered carefully and discussed, if necessary, with the individuals concerned. Although this intervention may suggest a possible corruption of the data, it is argued that these links would only be entered if they are logically justifiable and that their inclusion aids the understanding of the large project map. Clearly these links can only be considered because, by this stage, the researcher would be fully conversant with the particular case study and will therefore be able to apply a consideration of the global picture built up from individual contributions.

The analysis of the processed data culminates in the production of a combined project process map. The project cognitive map represents the combined perceptions of those who were influential in developing the design of the façade. This form of data collection therefore can claim to offer an opportunity to study the process of information flow, decision making, and design management which forms a key part of project management.

6.19 The significance of the methodology

The area of design management, or the management of the information flow, on complex construction projects has for the last five years been of increasing priority for many leading players within the industry. Yet beyond a title, the actual content of this subject area is open to significant interpretation and disagreement. The use of cognitive mapping, as applied to real projects, seeks to inform those practitioners involved in this complex area exactly what the scope of the subject is. As such it exploratory, and may only confirm that the subject is incapable of generalisation across such a heterogenous population set. There will however be lessons to be learnt regardless of the applicability of results. Firstly, the ability to condense a complex problematic into a series of readily understood areas should reveal a number of factors which all the concerned parties on a project would need to consider when managing the design. This information would then be ideal for incorporating into a strategic plan for managing the information flow necessary for complex projects. It is this area in particular where the greatest potential for improvement exists.

The next three chapters will analyse case studies drawn from the UK industry, focusing on the management of the façade and using the perceptions of the key decision makers involved which are analysed using cognitive mapping.

Chapter Seven
SmithKline Beecham Research & Development Project, Harlow, Essex

7.1 Project Background

SmithKline Beecham (SB) are one of the leading multinational pharmaceutical companies, with facilities located around the world. With a growth pattern which incorporates mergers and acquisitions, SB accumulate facilities which, on an asset basis, are often duplicating existing facilities or are dispersed geographically, resulting in operational and commercial inefficiencies. The new R&D facilities in Essex were a response to this situation as well as an acknowledgment that the modern needs for world class R&D in pharmaceuticals are increasingly incompatible with older facilities.

7.2 The SC1 Building

The current project, known as SC1, is the result of a programme of review that began in 1989 when SmithKline Beckman and Beecham merged to form SmithKline Beecham. A strategic review of the R&D facilities in the UK found that the existing 11 sites, comprising 2-3 buildings of 2-4,000m^2 each, located around the M25 were inefficient and costly. Part of the review process examined the needs of the key users, and found that there was a desire by the scientific experts, in many diverse fields, to work as teams. As there was substantial evidence of pharmaceutical successes enabled by the cross fertilisation of ideas and expertise across disciplines, such team working was seen as an important factor for future facility design. The full review, which considered a range of technical, scientific, operational, and commercial factors, was entitled Vision 2000 and acknowledged the desire of scientists to work in teams. This desire had to be achieved at minimum cost to the newly formed corporation. A calculation of the cost of building a new centralised R&D facility on a green field site was £550m which was far more than could be afforded. The results of the Vision 2000 review led to the compromise plan (UK '95) where the 11 existing sites would be rationalised down to five, each focusing on a research speciality.

SB appointed Orkit to provide the master plan for the redevelopment of the five sites and used Terry Farrell as the concept architect. Terry Farrell was appointed as an internationally renowned architect capable of redesigning the five sites in an attractive way. The Orkit/Farrell designs for the elevational treatments of the buildings on each site were different, reflecting each site's specific location and requirements. SB appointed AMEC Design to continue the design development, appointing them to carry out the 'Front End Study' (FES). This study validated and developed the design, while at the same time integrating detailed cost analysis. SB had used AMEC before, and AMEC were recognised as having an expertise in the design of process related buildings, with a requirement for complex M&E services. As a company with strong associations with the US, part of SB's management preferred the use of the Hillier and Associates architectural practice. This US practice is respected as the premier designer of laboratories in the US, and has connections with the US-based senior management of SB. Hillier had been brought in by SB to work with Farrell on the original schemes as the US practice is well versed in laboratory layouts.

As both Farrell and Hillier were capable of fulfilling the role of concept architect, there was a degree of tension about the underlying concepts on which each design was based. The position therefore developed where the same five sites were being considered by two independent concept architects, both feeding information into AMEC. The resultant situation was unusual and led to contradiction and ambiguity. AMEC continued to develop the selected concept designs. As the FES neared completion the cost estimate was submitted, and SB's main board approved a budget for the five projects of £220m.

As the FES was progressing on the five sites, SB discovered that BP were selling redundant property and land adjacent to their (SB's) existing facility at Harlow. The combination of 24,000m^2 of existing office accommodation, together with 66,000m^2 of land with outline planning permission, provided SB with the opportunity to substantially increase the plans for the Harlow site, which was one of the five sites chosen for redevelopment. The additional purchase of a key strip of land from the District Council which separated the plots, meant that SB had acquired a total of 213,000m^2 of available land which compared with 135,000m^2 it currently owned.

Since this opportunity allowed for the significant concentration of research at Harlow, the existing plans were scrapped and a new scheme developed. SB appointed Hillier and associates as the master planners and concept designers for the SC1 project, while SB carried out the project management of the early stages themselves. Key amongst the many tasks that were important for the overall success of the new project was a clear definition of needs for the new facility. Drawing upon the data generated in the original review, SB's operations manager drew the Vice Presidents from the different scientific specialities together and required them to limit the list of objectives for the facility to ten key factors which could be incorporated into the design. This exercise, referred to as 'simply the best', confirmed that by far the most important of the requirements was a design which enabled scientific interaction amongst individuals and multi-skilled teams. This resulted in a related demand for the design to be functionally flexible, thereby allowing a range of possible uses for laboratory areas. A further high priority was for the design to enable research scientists to have access to natural light and external views while working in the laboratories or writing up their experiments in separate offices.

As the new SC1 building was to be built using part of a slightly increased budget (the total budget was increased from £220m to £267m to allow for the purchase of the BP site and other land and an increase in the scope of the redevelopment, created by this unexpected bonus), the cost of the building had to be minimised where possible. This led to an important series of discussions where a design principle for the building was agreed with the research scientists who would ultimately use the building. Fundamentally, the issues centred on whether the laboratories or the write-up offices were located against the façade of the building. This was critical because the design centred on a building layout with a central service corridor feeding the laboratories. As the laboratories are extremely heavily serviced, there is compelling justification for locating them directly adjacent to the service corridor with the less heavily serviced offices located towards the exterior. This, however, meant that the scientists lost their direct external views from the laboratories. To resolve this, the design has a second fully glazed corridor between the laboratories and the offices. The resultant design was narrower and had less complicated service routes. A distinct practical advantage of this design decision is that the footprint of the building is smaller and enables the retention of an existing incinerator building which, if forced to be demolished, would have caused considerable difficulties with the planning authorities over the requirements of the replacement. The new building has an 'H' shaped footprint with the research specialities of biology and chemistry located in each wing. The central spar contains all key amenities including restaurant, library and lecture theatre and allows space for the important social interaction between researchers. Being an intensively serviced building, the floor to floor heights are greater than normal, being approximately five metres. The building has seven above ground levels, a lower ground floor, and basement. The space planning is on a 7.2 metre grid, which is transmitted to the outside using the mullions of the cladding.

7.3 The Pharmtech Building

In addition to the SC1 building, SB were having a pilot production plant built on a site very close to SC1. This project provides the facilities necessary to enable small scale commercial production of pharmaceuticals to take place. This is an increasingly important part of the commercial feasibility of the development of new drugs or production processes. In addition to the numerous statutory obligations which drug manufacturers have to comply with, manufacturers have to ensure that laboratory based procedures can be scaled up to produce commercially viable quantities. A pilot production plant enables such viability to be tested, without the necessity to invest in major production facilities. As a functional building, there was not the same requirement for an architecturally important design, however, the building represented another development for SB, and the result was a design which was more cost conscious, but which followed the ethos of the SC1 design.

7.4 The Project Players

a. The Client

The specific client for the SC1 project is the research and development subsidiary of SmithKline Beecham. The client organisation consisted of a senior operations manager who headed the R&D operations and who is a professional chemist. Reporting to him was a senior project manager, who handled the responsibility of the day-to-day management of the project. The senior project manager had a staff of approximately eight project mangers who, with a few support staff, were each responsible for a different section of the project. This dedicated team of approximately 12-15 were fully responsible for managing the client's interests. This client team was located in the existing offices, owned by the client, adjacent to the site. Feeding into this group were users who, in the form of representative committees, were originally involved in establishing the detailed needs of the building. The senior operations director had direct links to the main board of SmithKline Beecham, where strategic corporate decisions were taken.

b. The Master Planners and Concept Architects

Originally, when the scheme consisted of five separate redevelopments, the master planners were Orkit and the concept architect was Terry Farrell. Although unexpected events led to a much greater importance of the SC1 project, the user data gathering exercise had been commenced and was continued. This important stage , handled internally by SB, was critical for the later speed with which the revised project was able to proceed. For the SC1 project the new concept architect and master planner is the Hillier and Associates Practice from Princetown, New England, US, one of America's leading laboratory designers. The appointment followed an involvement on the original scheme as the practice was brought in to provide specialist advice on laboratory layout to Farrell. Bob Hillier, himself is a close personal friend of SmithKline Beecham's American CEO, was lobbied for strongly by the US division of SB, when the scheme was changed to incorporate the developments at SC1. The US practice was the base for the early design work, with AMEC representatives being flown over to assist and provide UK specific information.

c. Scheme and Detail Architect, Consultant Engineers

AMEC Design initially won the appointment for a thorough feasibility study, entitled the 'Front End Study'. Following the successful completion of this stage, AMEC's appointment was extended to include all detail design. AMEC's design responsibility covered architecture as well as structural and services engineering as an integrated package. Although they had to beat competition from a consortium of Sheppard Robson and Ove Arup, AMEC offered a fully integrated design team who were used to complex, large scale design projects. AMEC Design are part of the AMEC Design and Management organisation which offers a single point of responsibility for clients. On this project, however, the design section was appointed only for design services under a fixed lump sum contract.

d. **Professional Quantity Surveyor/Cost Consultant**

The role of the PQS is much reduced on this project. The use of an integrated design team used to working on Design & Manage contracts meant that the design was progressed with a constant consideration for the cost implications. Design progress meetings and reviews were therefore not merely technical in nature but included detailed financial considerations. AMEC employed 'building economists' who acted as internal quantity surveyors/cost consultants and, as internal advisors, greatly reduce the complex task of calculating projected costs from a developing design. SB employed a cost consultant in an auditing role to confirm the costs proposed by AMEC.

e. **Cladding Consultant**

Cladtech a small specialist consultancy were employed by SmithKline Beecham as an additional source of expertise for the development of the façade design. The duties of Cladtech were to advise on technical issues and provide additional scrutiny to both the on and off-site activities of the cladding contractor. This wide ranging brief also included the writing of the performance specification which was to be used as the primary source of control for the quality and longevity of the façade installation.

f. **The Management Contractor**

LMK, a joint venture between Laing Management and Morrison Knudson, were appointed to the role in early 1994. LMK had recently worked on the Glaxo R&D facility (See chapter five) in Stevenage and therefore brought considerable recent experience of large scale laboratory construction using fast track methods. They were appointed under a standard JCT form of management contract.

As well as procuring and administering the trade contracts, LMK also provided the second stage of a two stage design cost control system. Dealing with mainly design changes, LMK estimated the likely cost of alterations which had been proposed by the designers. The first stage was where any design costs were initially calculated by the designers on a standard sheet, known as Project Design Notes (PDN's) which recorded who proposed the change, why the change was proposed, and how much it was likely to cost. A regular review meeting considered these individual requests and decided which were worth considering in greater detail. Those which were judged worthwhile or necessary were then passed onto LMK for detailed cost and programme implications. The results were again reviewed by the client and, where budget and time constraints allowed, the request may have been granted.

g. The Trade Contractor

HarmonCFEM were a new company formed by the takeover of the French firm CFEM by the American firm Harmon. Harmon themselves are owned by the Apergy Corporation, an extremely large US conglomerate. The takeover of CFEM followed the results of CFEM working on a large project in the City of London which went badly wrong and which led to CFEM being unable to continue trading. Harmon had a small UK company, but sought to exploit the European market, and saw their opportunity in the ailing CFEM. The SB contract on the SC1 project was primarily negotiated by the American parent company, and it was only because the Parent Company Guarantee was signed by Harmon representatives and endorsed by Apergy, that the contract was awarded to HarmonCFEM. HarmonCFEM itself was run operationally by the two former directors of CFEM who are French, with additional management support, particularly in marketing, being provided by the US.

Figure 7.1, on the following page, illustrates the contractual relationships and main communication routes on the SC1 project.

7.5 The façade

The new R&D facility being built at Harlow was seen as a necessary project by the client because it would enable the rationalisation of R&D into a more concentrated area while providing enhanced facilities and a better working environment for the research scientists. As such, the building was justified as a capital asset which enabled key research to be carried out. The emphasis was therefore on providing a sophisticated series of research facilities, integrated within a modern building which was also pleasant to work in. These primary design parameters focused on the internal building layout with particular emphasis on the laboratory facilities and services and sufficient space for social interaction. The external appearance of the building was, in terms of size and layout, dictated by the function of the

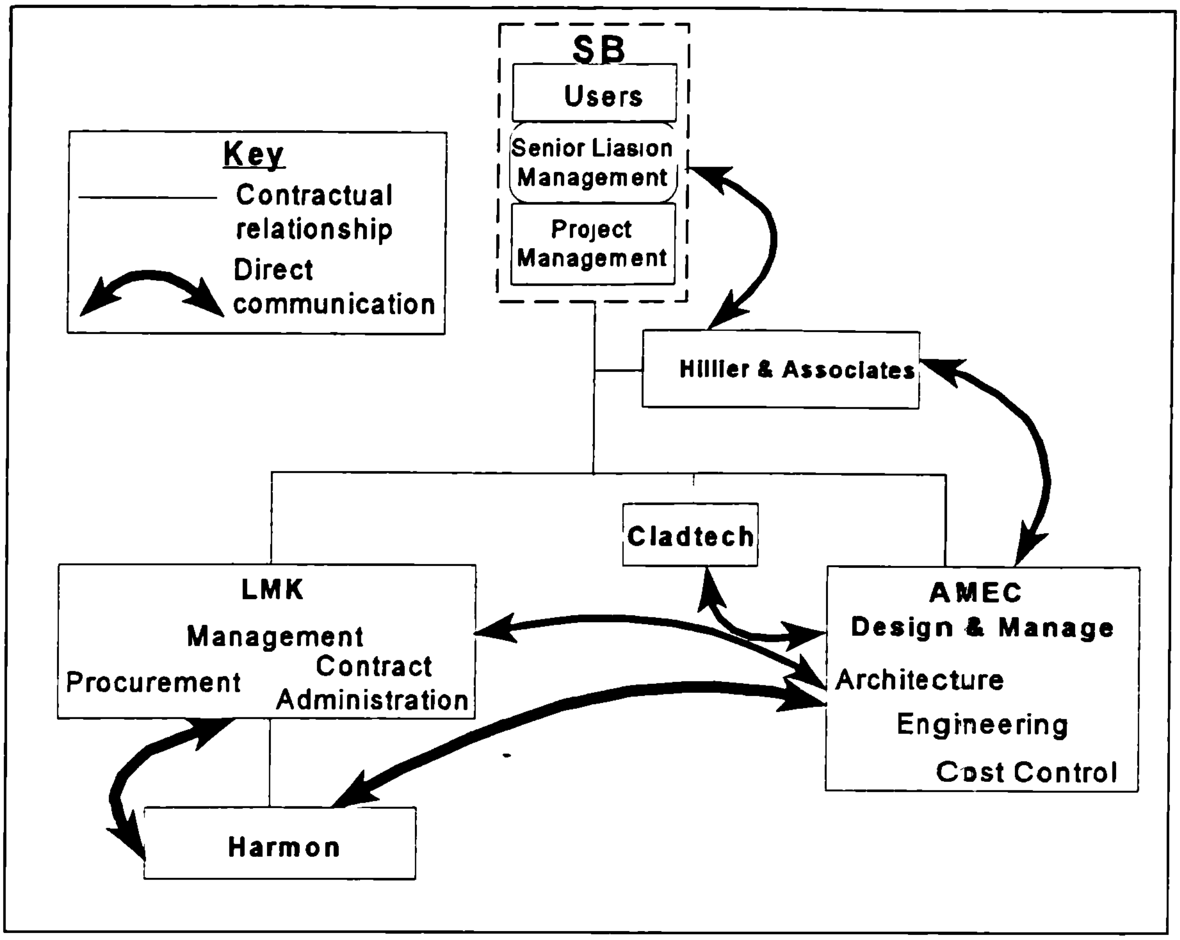


Figure 7.1 Contractual relationships and information flows

new building, and the constraints imposed by the existing buildings. The façade of the building was not of primary importance *per se*. Although not a key driver of the project, the façade was of significant importance because of its cost, its contribution to the overall appearance of the building, and because of the demands of the scientists for good views and natural daylight.

Given this situation, the architect had the opportunity to clad the building in a number of ways. To develop a solution, Hillier held an internal design competition amongst a selected group of their architects who had either worked directly on the SC1 project or who had a good understanding of the constraints imposed. The results of this exercise were seven entirely different proposals. It was necessary to evaluate the approximate costs of each of the proposed designs to ensure they were affordable. To evaluate the different designs, all the schemes were produced to the same scale, using the same artistic style of presentation, which enabled direct comparison. These seven options were submitted, by the architect, to the client and project team which were, at the time, located in the Hillier offices in the US. The judging process was carried out along democratic lines, with each individual given a vote which they were free to use to select the design they felt was the best. The selection committee of senior personnel reduced the seven choices to three. These two separate options (and a hybrid third) were then examined in closer detail and more emphasis placed on the cost. The budget costing carried out was on a per square metre basis.

As the cladding forms a significant part of the overall cost of the project, the decision for the final choice was transferred to the main board of SB. The choice lay between a stone and glass façade and an all glass façade; the final decision, made by two senior directors, was for the all glass façade. It would appear that this choice was based on aesthetics and achieving the maximum amount of daylight. From a buildability viewpoint the preferred design was relatively straightforward, combining different types of tinted double glazed units in a white powder coated aluminium frame which was clipped to the reinforced concrete structure using recognised methods. The glazing consisted of opaque panels up to cill height, cill to ceiling tinted clear glass, and a contrasting coloured glass panel covering the ceiling service void and up to the start of the next floor. The overall effect was of simple, modern clean lines which reflect well the nature of the operations carried out within the building.

As a key requirement was for future flexibility, there was a great deal of deliberating over the layout of the major building components. Main elements, including stair and lift cores, service cores, and structural supports, were all located so that the internal floor space was open to future adaptation. The stair and lift cores were located around the perimeter, and service riser cores were grouped to minimise their number. The distribution of services to the perimeter of the building became a problem. With such an open floor plate, there were few routes open to drop the services to bench level. This was resolved by introducing trunking to the internal face of the mullions, enabling a service route to be created. The result was an elegant way of dropping piped services, power, and data and telecommunication services to be fed to outlet points in a coordinated manner. By introducing the use of the cladding as a service route, there was the possibility of expanding the service capacity for the future, thus achieving a major client requirement.

Following the choice of style for the façade the design was initially developed by the Hillier practice. The SB project manager responsible for the external elements, including the façade, had previous project management experience with property development companies and recommended that a specialist façade consultant be appointed. This recommendation was supported by the US architectural practice which routinely had the façade design reviewed by experts in order to avoid any claim of negligence. A UK company, Cladtech, was appointed for this role and worked with both the concept architect and AMEC and ensured that the design would be functionally adequate and satisfied all the applicable planning regulations. It was the view of the cladding consultant that the budget allocated for the cladding was the absolute minimum necessary to achieve the selected design solution.

Once the design had progressed to a point of reasonable detail and certainty, the scheme was formally costed to secure a budget, and drawings and specifications were submitted for planning approval. The budget was approved in August 1994 and planning approval was granted in mid September. The first piles were driven two days after receiving planning consent.

As the design for the cladding was affected by the working details of the particular system selected, there was a recognition that the cladding contractor was needed to be selected early enough to be able to develop the design. As there were many components which had to be manufactured assembled, and then tested, there was a substantial lead in time required before site works could commence. The cladding was therefore one of the first works packages to be let. It was the second substantial package to be let after the superstructure, which was more straightforward. The commercial considerations affecting the selection of contractual arrangement were for the client to achieve price certainty.

While recognising that the design required to be developed by the contractor. The decision was made to go for a fixed lump sum tender using a JCT 81 form of contract which included contractor design development. This achieved both objectives of price certainty, and design flexibility. For this procurement route to be successful, there was the need for the design information, on which the tender was based, to be logically complete, and clear. This put significant pressure on the AMEC design team, who, having taken over the design from Hillier, had 12 weeks to take the design from an outline concept, through to a series of detailed drawings and specifications. The scope of the works included all the exterior cladding, including atria, and structural glazed walls which were a dramatic design feature. In addition, the cladding package included all the rooftop cladding, which was a substantial amount, as there were a lot of louvres to cover the plant room areas, and flue stacks.

A worldwide search indicated that the vast majority of competent companies were foreign. The only British company on the list were Crittall Windows Ltd, as they were a local company and there was political pressure to ensure that UK companies were allowed to tender for work where possible. An extensive pre-tender selection period followed, with interviews and references being taken and checked. The project team responsible for procuring the cladding wanted to ensure that the companies placed on the tender list would be committed to working for the success of the project. The criteria for interviewing the contractors, which was made clear from initial invitations, was that the interested companies demonstrated a clear understanding of what the project entailed, what their response was likely to be, how they would break the job down, and what they thought the key areas and problems were likely to be. To assist the competing companies performances at interview, a mark sheet was developed which identified all the main areas which were important to the selection team. The initial long list of contractors contained 12 companies which was to be reduced to six for the full tendering.

Of the many companies that responded to the invitation, of interest was the performance of Harmon, based in the US and one of the largest cladding contractors in the world. With such a reputation, and a recognition of their project management skills, it was a great surprise for the project team when Harmon's performance at interview was very mediocre. Individual impressions of Harmon's performance varied amongst the selection team, but it was clear to all that Harmon relied on a very slick presentation based upon their size and experience. Harmon failed to address the particular needs of the SC1 project, concentrating on their previous successes. This resulted in substantial discussion on whether to include Harmon as one of the final tenderers. As the scores indicated that Harmon should not be put on the tender list, but the personal views of some members of the team varied, it was agreed that Harmon were to be given another opportunity to present. This decision was possibly influenced by Harmon's senior managers' discovery of their poor performance, and their direct contacting of senior managers and directors of the management contractor, explaining their presentation, and requesting another chance. The result was that Harmon were allowed a second chance. Harmon's second presentation was far better, showing a clear commitment. The final tender list included both Harmon and Crittall Windows Ltd.

The tenders were returned and tender evaluation commenced. As each company was able to apply their preferred system to the design intent indicated by the drawings and specifications, a range of different systems were proposed. The key difference in systems was the use of 'stick and post' form of construction, or panellised systems. Panel systems are usually more expensive than stick and post systems, but allow faster site erection times, with more uniform quality, due to the higher content of off-site pre-fabrication. Panel systems are commonly found on high rise buildings, where there is much repetition of panel size. Of the lowest three tenders returned, the proposals were for a stick-and-post systems, which was expected by the project coalition, as the budget and specification had suggested that a panel system would be too expensive. The three lowest tenders came from CIR, an Italian cooperative, HarmonCFEM who were the recently created French base for Harmon, formed by Harmon's take over of CFEM, a struggling French contractor, and Permastelesa, another Italian company.

Having focused attention on these three companies, the selecting team began a detailed appraisal of tne bids submitted. It quickly became apparent that Permastelisa's bid was not of the required technical standard, and they were eliminated from the selection. Having established the competence of the bids from HarmonCFEM and CIR, the designs of each company were scrutinised. To do this fully, the designers from each company were requested to attend meetings with the project team, where the assumptions, qualifications, and details of each proposed design could be analysed carefully. While the CIR designers remained attached to their stick-and-post design, which they were very familiar with, Harmon brought one of their best US designers over for the meeting. This meeting proved to be crucial because the designer used skill, expertise, and vision to redesign the project, based on an astute understanding of what was required. The key change was that he switched from a stick-and-post based design to a panellised solution, at no extra cost. This was confirmed by Harmon's commercial managers, and put Harmon in a strong position.

The results of the tendering for the SC1 building had an affect on the likely success of the tendering for the cladding on the Pharmtech building. Although managed as completely independent projects, the nature of cladding meant that some firms were placed on both tender lists. As the SC1 project was more advanced, the results of the tender were known before the tenders were sent out on Pharmtech. Some companies that had appeared on both lists had been interested in the smaller Pharmtech project only as an addition to the much larger SC1 project. Hence, when they found out that they were unsuccessful on SC1, they withdrew their interest for the cladding on the Pharmtech project.

It was at this stage that senior corporate SB managers, to whom those SB managers working on the project were responsible, requested that, as a money saving method, the cladding of the Pharmtech project was included as part of the cladding contract for the SC1 building, and offered to the lowest tenderers on SC1. This request was not supported by either of the management contractors for the two projects, who felt that the substantial increase in workloads, introduced at such a late stage, would create too great a pressure on the trade contractor, particularly as both management contractors would require separate accountability. These concerns were overruled by SB and, as the Pharmtech building's design was not as advanced as that of SC1, the opportunity existed to apply the principles of the SC1 cladding design to the Pharmtech building.

Having made the decision to include the Pharmtech's cladding to the scope of works for the existing tender, SB entered into direct negotiation with CIR and HarmonCFEM concerning the additional work. SB were looking for discounts to the rates applied to the SC1 element of the combined tender to reflect the expected economies of scale for such a substantial increase in work.

At the same time a small delegation of project coalition representatives were authorised to visit the offices and production facilities of the two final tenderers. This three person team comprised the SB project manager responsible for the cladding, the LMK manager responsible for the shell and core and the AMEC architect responsible for the cladding's detail design for the SC1 project. To assist in their evaluation of the two companies, they used a score sheet to identify individual aspects of each companies facilities and personnel. The result of the trip was a very small difference in scores, but the technical report, prepared by AMEC, recommended Harmon, based largely on their decision to use a panel based system. The commercial report, produced by LMK, and based on the returned tender for SC1, recommended CIR. This left a split decision, with SB having the final say. Given SB's direct negotiations with both HarmonCFEM and CIR, the tender was finally awarded to HarmonCFEM, as they had offered a substantial discount, and became the lowest tenderer.

The next stage in the development of the cladding's design was the transfer of responsibility from AMEC to the trade contractor. To enable the smoothest transition, and to establish a framework for the comment and approval of HarmonCFEM's design, the architect responsible for developing the design, (DB), together with the cladding consultant, (PP), went to visit the design offices of the new company near Paris, in France. From the outset, the management of the design by HarmonCFEM was not carried out as expected by the visiting project representatives. There was a lack of strategic direction in the way the design was progressed by Harmon, with a failure of their lead designer to get involved, which was what the project coalition had been led to believe. Harmon sought to provide a number of individuals, sometimes singularly, sometimes as whole teams, who would arrive to progress the design. The individuals sent by Harmon were of various nationalities, including a Russian structural engineer working with Americans, and these personnel were changed without warning. This led to both confusion and delay, as the different groups of individuals needed to understand the idiosyncrasies of the SC1 design as well as provide an integrated and coordinated plan for the development of the cladding. The one constant presence from the Harmon design team was the Frenchman who had worked for CFEM before the acquisition by Harmon. He, although titled as the design manager, actually followed the lead of the other, more temporary individuals. As the majority of technicians who worked on the CAD system, together with the production personnel, were French, the design manager, who was bilingual, spent a significant proportion of his time translating.

The result was that the period of time designated for design development was lost. Elements of the design were progressed, but the items selected tended to be clearly separated from the overall design, and tended to be classified as the easy parts of the design. Some elements were successfully handled, most noticeably the design of the standard panel which was designed, built as a test panel and successfully tested and certified. The other successful piece of design was the development of a new form of fixing bracket, which is a simple and elegant piece of design engineering, enables easy installation, accommodates wide tolerances in the structure and which is applicable to a wide range of structural situations. These design elements were, however, the exception, and, of most concern to the project coalition, the progress of the design appeared to follow a random approach rather than a pre-planned and coordinated strategy. This lack of design planning was evident by the failure of HarmonCFEM to produce the associated paperwork and programmes which were both contractually necessary, as well as being of great assistance to the management contractor who was required to coordinate a number of trade packages on site.

The lack of a coordinated approach from the trade contractor to the design was mirrored by the lack of planning for production and site erection. The combination of such an uncoordinated approach was apparent to those from the project coalition who had responsibility for progressing specific parts. From the AMEC architect, DB, and including the cladding consultant, PP, to the LMK shell and core manager, JI, there was great concern, and ultimately a dramatic increase in time and effort spent by these individuals in an attempt to try an resolve the myriad problems. Such a response created associated problems, in other areas of the project due to the preoccupation with the cladding.

The start on site by HarmonCFEM was achieved within a few weeks of their planned start. This reassurance was short lived because the agreed order in which the installation would progress was not followed, with both the starting location, and the order of panel placement, being different. The order of installation was quickly determined by the availability of panels, which were sent to site direct from France. Although many deliveries were made to site, the required panels for immediate installation were often not sent, while many panels of the same type were sent. This had a double negative effect, as not only was the installation often stalled due to a lack of the right panels, but the storage of panels not immediately required became a significant problem. Indeed the support frames used to transport the panels, were all located on site, storing panels which could not be fitted, while the factory had no frames left to use to transport the panels which were necessary. Other significant problems were related to the delay in producing the panels, which put the production staff under enormous pressure, so jeopardising the benefits of controlled off-site production. Elements of the panel, which were primarily decorative, were left off in order to speed up delivery. This decision, while achieving a quicker turnaround, left the site installers with the requirement to fix these items on site, which was time consuming, subject to far greater variations in quality and cost substantially more because of the access requirements.

After panels had begun being installed, third party checks found that some batches of panels had received sub-standard paint finishes. As the faulty panels had only been found by chance, the problem created was that the panels had been erected as part of main elevation cladding. Having had such problems in getting the cladding to a point where it could start, there was a reluctance to remove the substandard panels. An alternative was to try and repair the fault *in situ*, which was tried and found to be unsuccessful. Finally it was decided to accept the fault in the installed panels and receive compensation, while ensuring that all panels that had not been installed were thoroughly checked and, where necessary, sent back for remedial works. The result of this, was an internal decision by Harmon to cancel their contract with their supplier of pre-finished aluminium sections and to replace that company with another. This fundamental change to their operations had a consequent delay to all production, and ultimately site works. This put the production schedule even further into delay, with a subsequent increase in the pressure on the production personnel to manufacture quickly. As a response they batch produced similar panels, regardless of site needs, exacerbating an existing problem.

As the project progressed, so the installation of the standard areas and details was rapidly completed. This followed the general plan which Harmon had used in both design and production. The parts left, some of which were still at the design stage when the site could have been installing them, were the very complicated areas or details. As they were generally left to the end, there was both a positive and negative argument for this. The positive argument was that the skill base gained through the solution of all the other more straightforward problems would enable a better solution to the found, both in design and manufacturing terms. The opposing argument was that the complexity of the details left was of such a magnitude that no good solution was realistically possible. By not considering the problems earlier, the search for solutions was constrained by a lack of time and resource as Harmon tackled the problems late into the contract with respect to other items. This combination meant that the first workable solution found was adopted.

The next stage will consider the individual perceptions of the management of the façade's design from those who were directly involved in key aspects of this element of the project.

7.6 The Analysis of the Cognitive Maps on the SC1 Façade

The data collected from the interviewees was in the form of transcribed detailed notes. This was then processed using the cognitive mapping software, Graphics Cope. For a detailed account of the methodology, see chapter 6.

A number of individuals, from various organisations, were involved in the design management of the façade on the SC1 project. The order of analysis follows the order of involvement of these individuals concerned. Although a great deal of information was communicated, the following analysis will consider only that which is directly attributable to the results of the cognitive mapping analysis, which culminate in the summary maps, illustrated below. The objective is to understand the complexity of the design management process in a way which is not readily apparent from traditional qualitative techniques.

a. MW, SB Senior Project Manager

MW was responsible to the SB client organisation for the delivery of the completed project within the constraints imposed by the client organisation. His role was to ensure that the strategy for managing the project was both developed and enacted by his project staff, as well as by the other project players.

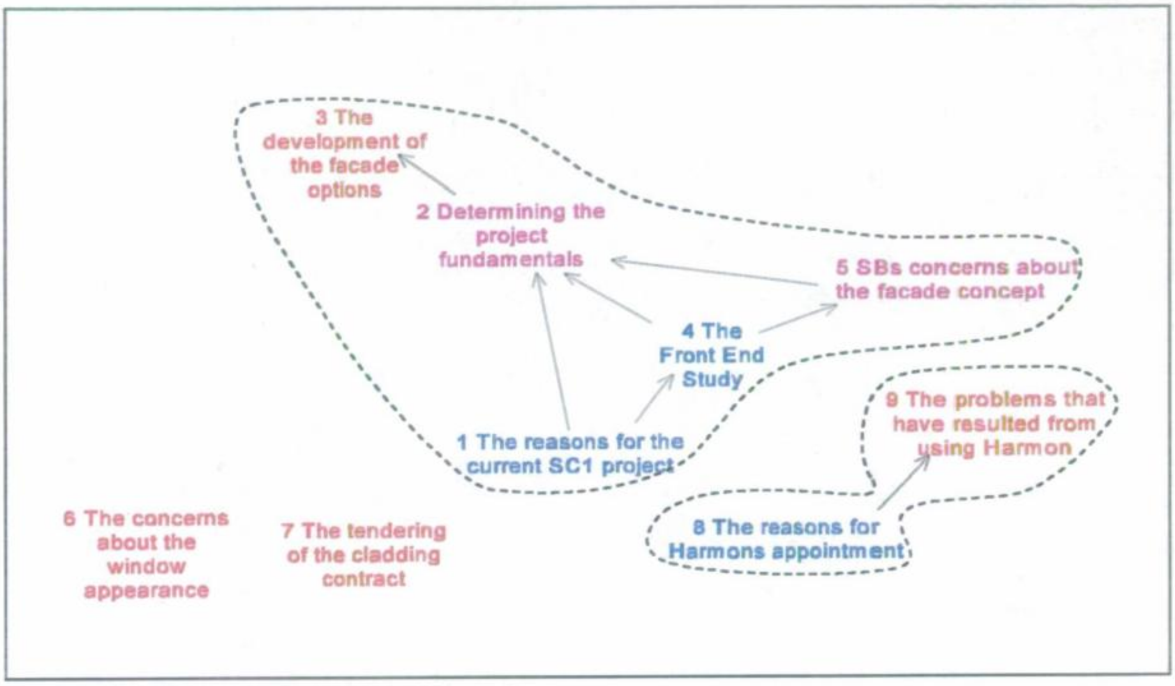


Figure 7.2 MW Summary Cognitive Map

The cognitive map produced from the interview (figure 7.2) indicates the relative importance of the façade to the project and also indicates as a separate issue, how the appointment of the trade contractor led to problems. What is of interest in this cluster summary is the lack of link between the acknowledgement that the cladding was on the critical path on the project, where the time to completion was the key objective, and the appointment of the trade contractor. This link, identifiable as the tendering of the contract, is left in isolation (7). Although recognised as being important, the failure to use the tendering period as the review period where important objectives are amalgamated, possibly suggests that there was a missed opportunity. Examination of the contents of clusters 8 and 9 (see appendix 2a) reveal that the trade contractor was seen to have a separate agenda for gaining the work - as a market entry tactic into the UK (appendix 2a, concept 2187). As this was given as a starting position from which HarmonCFEM operated, it is interesting that this perception did not appear to change the procedures which were used to procure trade contractors and that the introduction of the Pharmtech project, as an addition to the scope of works to the main SC1 project, was not part of the intended plan, and was therefore introduced without the same level of consideration.

The effect on the trade contractor of being awarded the project in its revised form was to impose enormous pressure on their organisation. Although the role of Cladtech is identified in cluster 9 as being important to the project, it was clear that HarmonCFEM was responsible for the post tender design development. From the cognitive map it is clear that the problems which HarmonCFEM caused were all related to the difficulty they had in gearing up for the start. The loss of a complete month early on meant that there was no opportunity to utilise the important information which was generated during the tender period. Thus for example, the decision to change from stick-and-post to a panellised system needed to be worked on to achieve a design solution which was acceptable to the project designers, while being commercially viable for HarmonCFEM. As the demands of the various members of the project coalition increased, ranging from programmes and schedules to detail drawings, so the pressure on the HarmonCFEM personnel increased. This initial pressure on the design personnel extended onto the general management, with witnessed failures of the quality assurance procedures resulting in the sending to site of substandard materials. As the initial problems experienced by the project design personnel were confirmed by project personnel from other areas, so the concern of senior management was alerted. The problems with HarmonCFEM on either site (SC1 or Pharmtech) were compounded by the fact that the two projects were being run separately. The delays initially led to a competitive situation developing between the projects which significantly increased the pressure on HarmonCFEM (appendix 2a, concept 2204).

As a response to the problems with HarmonCFEM there was the direct, and extensive, involvement of the LMK Project Director, which was seen to be an indication of the magnitude of the problem (appendix 2a, concept 2207). As noted by MW, the compounding of the problems created by HarmonCFEM led to the risk that they may consider walking away from the project. Such an eventuality was taken seriously, and can be related back directly to the events which occurred during the tender period.

b. **AS, SB Project Manager for the façade**

AS's involvement on the design management of the façade was more detailed as he had responsibility for this element of the project as part of a portfolio of elements that related to the structure of the building rather than its complex fit out. AS had previous experience with complex façades and was the prime motivator in getting approval for the appointment of an independent cladding consultant.

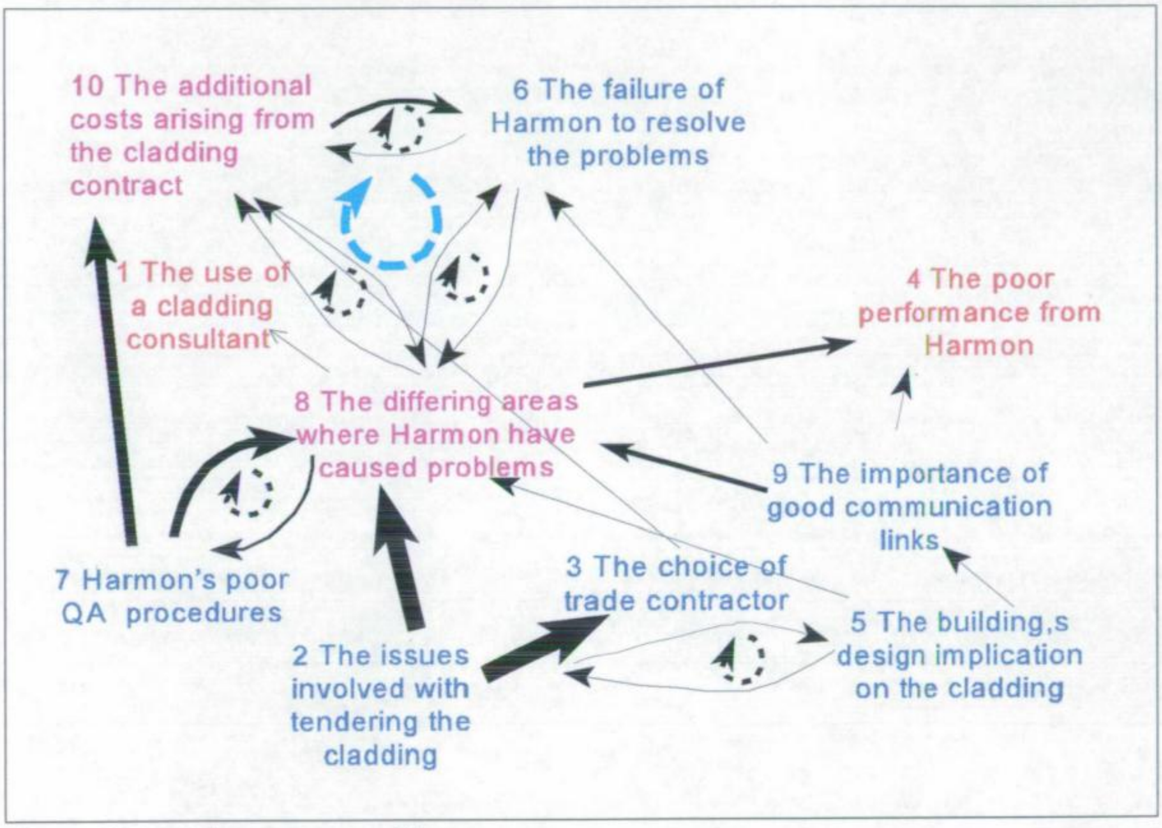


Figure 7.3 AS Summary cognitive map

The cognitive map shown in figure 7.3 clearly identifies the complexity of the problems associated with the façade. The summary map recognises the interrelationship of the various issues, with one process in particular, identified as cluster 8, 'The differing areas where HarmonCFEM have caused problems', being the central issue.

This complex cognitive map introduces an important feature, with six loops identified, four of which are linked to the central cluster. The loops relate to the relationship between HarmonCFEM's poor QA procedures, the failure of HarmonCFEM to resolve the problems, and the additional costs arising from the cladding contract. For example, a set of poor QA procedures led to the delivery of substandard items to site which were not spotted in time. The realisation that these items had been installed led to cost implications (cluster 10) which added to the problems which HarmonCFEM had to resolve, and created a loop back into the additional costs cluster. The problems with the substandard materials also led to a change of supplier, which led to delay and increased pressure on HarmonCFEM. The pressure to produce the panels quickly led, in turn, to pressure on the QA procedures.

The most important links between clusters are the link between the issues involved in tendering, the choice of contractor (2→3), and the varying problems which HarmonCFEM have caused (2→8). If the tendering cluster is seen as being the starting point from which the cognitive map is built, then the main points which are worthy of consideration are the need for good communication skills, the importance of QA procedures, and how the appointment of an outside consultant does not necessarily solve the myriad of problems that can be created.

c. **JM, AMEC Senior Project Engineer**

JM fulfilled two objectives on the SC1 project. He was the senior design professional from AMEC on the project, which meant that he was able to provide a clear view of where the cladding fitted in to the overall scheme. Secondly, and importantly for the research, JM was present during the master planning stage which was carried out in the US. This insight into the early master planning and concept design stages provided a useful addition to the completeness of the data. One of the key factors to come out of this interview was the importance of the fire engineering to the whole of the project's design and, in particular, the design management of the façade.

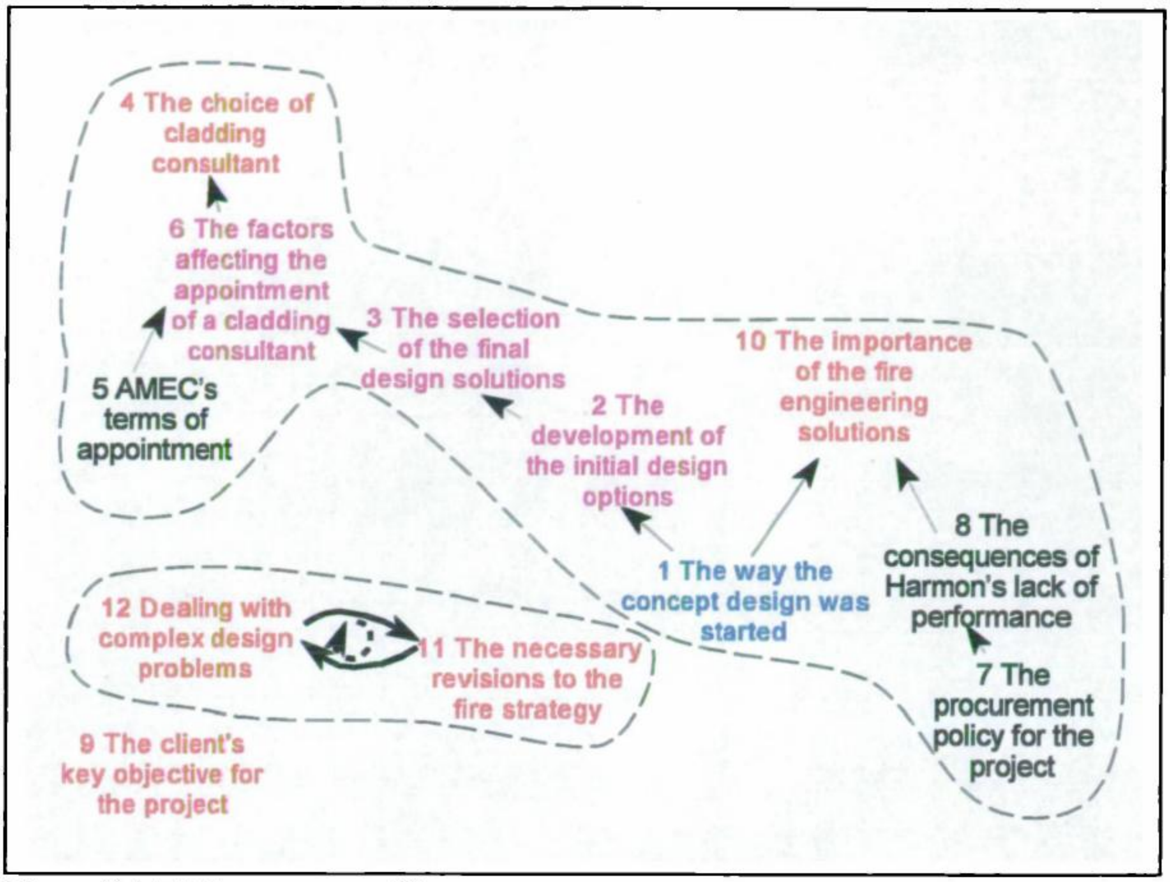


Figure 7.4 JM Summary cognitive map

The summary map (figure 7.4) has three elements: a series of linked concepts representing the main process, a secondary map which deals with the complexity of the design and an isolated cluster (9). The main map in figure 7.4 combines a number of elements, ranging from procurement policy (7) and AMEC's terms of appointment (5), through to the factors affecting the choice of the cladding contractor (4). The head clusters 4 and 10 illustrate how the decisions were taken which affected the cladding. Cluster 4 indicates that the project members were aware of the range of skills which the consultants had to offer. What is interesting is that there was no clear specification, rather an avoidance of skills which were incompatible with the project's constraints.

In contrast, the decision to appoint a cladding consultant was not linked to the complex requirements of the fire engineering and other elements of the building, including the façade and building security. This omission was not through carelessness, but appears to be due to the high degree of complexity of the design parameters and the design team's lack of experience in dealing with such complexity. It should be noted that the degree of complexity required by the facility, together with the short timescale between commission and completion, meant that such omissions were more likely.

The isolation of clusters 11 and 12 deal with the problems associated with a complex and novel design, illustrate how AMEC's resources were employed in trying to resolve many problems which were created by combining a complex set of objectives for the building with a complex design. This reaction to circumstances explains the lack of ability to factor such issues into the selection criteria of the cladding consultant.

Cluster 9 relates solely to the acknowledgement that the client wanted to procure the building as quickly as possible. JM speculated as to whether they have specifically held money for the contingency of claims. If this policy is correct it could explain a number of issues related to the failure to fully consider the interrelationships of issues such as the fire engineering.

d. PP, Cladtech Associate's Cladding consultant

PP was appointed as the cladding consultant for a number of reasons. He had worked previously with AS and therefore was a known quantity. He was not considered a risk to the design intent of the concept as he focused on ensuring appropriate specifications and conformance of detail design and production quality. He was also well acquainted with the large contracting companies that were likely to be involved on the cladding. This range of skills was ideally suited to the required role of an advisor and writer of the specification documents. In terms of overall contribution to the success of the cladding, PP was in a position theoretically to be most influential, yet for what were explained to be simply budgetary reasons associated with the cost of sending an additional person on the trip to evaluate the two final tenderers, this was not to be.

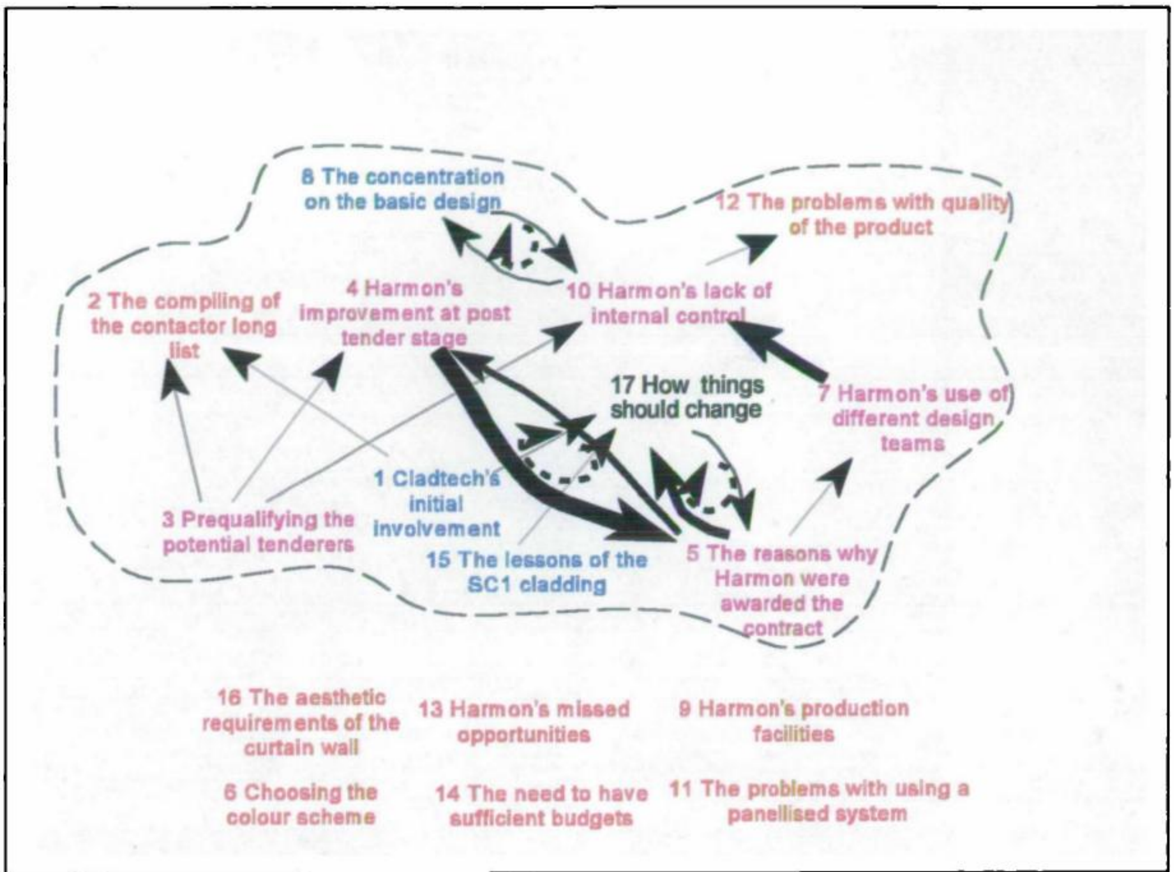


Figure 7.5 PP Summary cognitive map

An examination of the cognitive map in figure 7.5 reveals a complicated process which relates several key issues. The focus on the issues relating to the tender process indicates PP identified causal factors in the tender stage that led to the appointment of a contractor with the potential to cause problems. The loops which appear in this cognitive map relate to the way HarmonCFEM were selected, and the problems caused by HarmonCFEM's lack of internal control. The first, and most significant, loop between clusters 4 and 5 explains how HarmonCFEM were allowed another opportunity to explain their ideas for the project. As an objective scoring system had been developed in order that competing contractors could be evaluated according to the desired objectives of the project, it was clearly subjective factors that allowed HarmonCFEM to have a second chance when their first performance at interview was significantly less than satisfactory. If the rational system had been employed without interference, HarmonCFEM would not have been put on the tender list.

PP, who was specifically engaged to advise on the performance of the contractor, was not fully included in this stage and was specifically excluded from the visits to see the facilities which the companies proposed to use (appendix 2d, concept 91). It is clear that PP had relevant experience of evaluating contractors (appendix 2d, concept 100). The only experience that Cladtech had with HarmonCFEM was with Harmon prior to the takeover of CFEM (appendix 2d, concepts 92 & 93) and therefore to make a direct comparison between these two competing organisations it was necessary to fully involve all those capable of evaluating all the available evidence, which would have included PP.

Further analysis of figure 7.5 reveals a number of factors which led to Harmon's lack of internal control (cluster 10). The combination of a changing design team and a focus on the standard design contributed to the problem, which ultimately affected the quality of the product.

The final point of the cognitive map is the way the problems encountered on the project should be used to inform changes for the future. The recommendations reflect the experiences gained from agreeing contracts based on exceptionally low prices with a company with whom there was no prior relationship. Thus, PP's view was for a tacit acceptance of the right of all parties to make a reasonable profit, and of the development of long term relationships between differing parties.

e. **DB, AMEC Architect responsible for the cladding design**

DB proved to be the key player in progressing the design through to the point where manufacture could commence. The interview with DB was by far the longest and, as would be expected, covered the widest range of issues and went into significant detail. The summary cognitive map shown in figure 7.6 is most revealing because it starts with the expectation of how the design was to proceed. This revolved around the use of design reviews to ensure that the contractor enhanced the design in accordance with the design intent. This approach would also circumvent the need for formal submission and approval of drawings before manufacture could proceed. The experience of what then followed provides a useful insight into the factors which affected the management of a complex design.

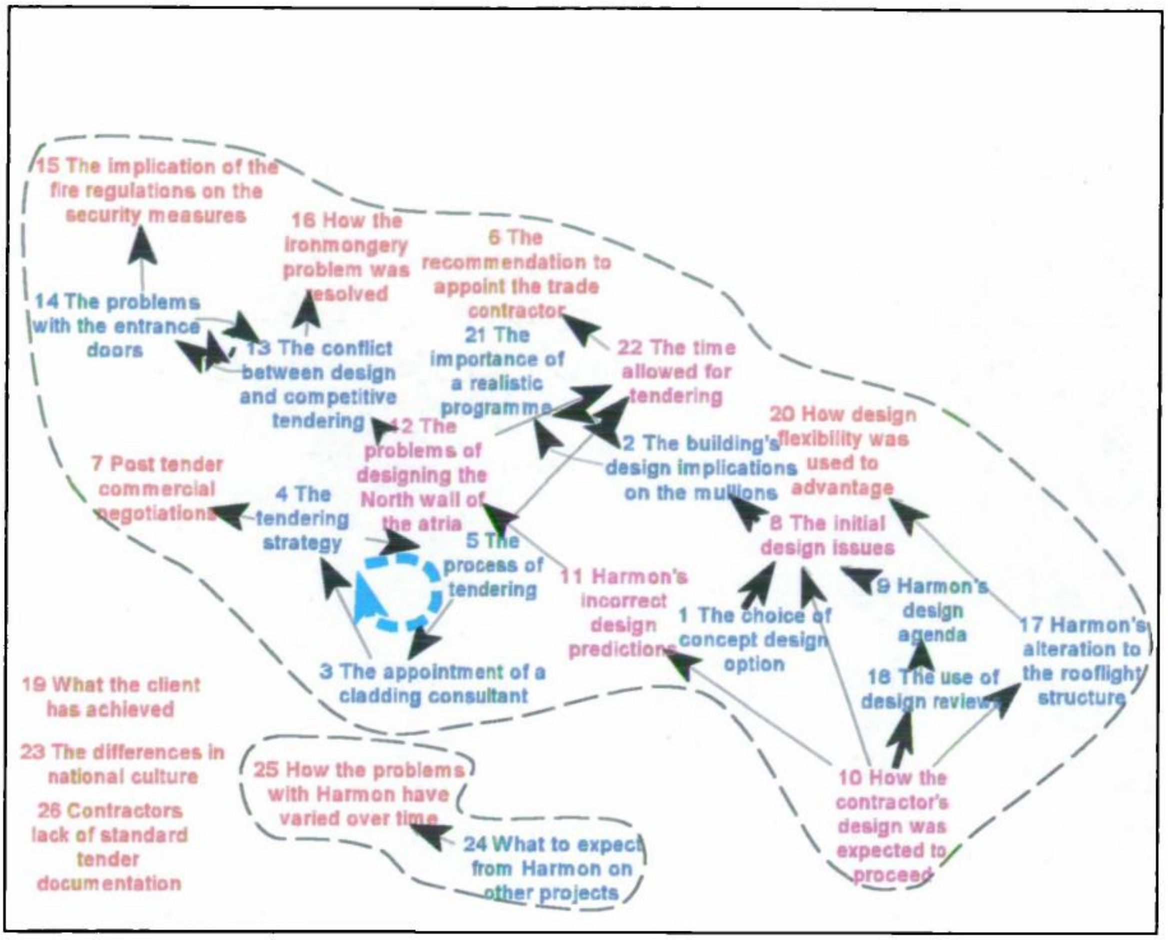


Figure 7.6 DB Summary Cognitive Map

The summary map shown in figure 7.6 builds from expectations of how the design would progress and brings in a number of issues related to the early phases of the project (cluster 8). These early issues were themselves subject to influence from the client to achieve the objective of completing the building in the shortest time, whilst ensuring minimal commercial risk to the client. Problems were created by the need to advance the design quickly, with a significant input from the trade contractor, while maintaining price surety for the client. This leads to the loop between clusters 2 and 21. A similar problem was found with the entrance doors, with the client desiring extremely well designed and robust doors while the trade contractor wanted to offer the cheapest option. This led to the loop between clusters 13 and 14. There were areas, which are covered in the cognitive map, where the design management went well. The way the philosophy of the design was used to enable necessary changes in the windows for the flue towers (cluster 20) demonstrates that when the problem is clearly understood, and where the correct people are involved at the appropriate time, potentially complex problems are averted. This argument is reinforced by the account of how the ironmongery issue was resolved (cluster 16). Where this approach was not followed, as in the case of the North wall of the atrium (cluster 12), significant problems easily developed which may have escalated into political issues. The partial fragmentation of the team mentality during the latter stages of the tender negotiations for the cladding, when SB managers pursued commercial discounts, introduced a new range of factors into the management of the design which were not immediately obvious, but which were apparent to both DB (cluster 7) and PP (PP cluster 14).

The final area of interest is the loop involving the tender stage. Here, the developed strategy for the cladding, involving the use of the cladding consultant, reinforced itself. By bringing in the cladding consultant, the process was reinforced and enabled a better strategy which required a cladding consultant's input.

f. IJ, LMK Head of Engineering

IJ was not directly involved in the management of the design on the cladding but did have an involvement in the interface management which required input from the cladding design. IJ was the first to be interviewed and this allowed for both practice of the technique and a general overview of the project to be gained prior to discussions with the other interviewees.

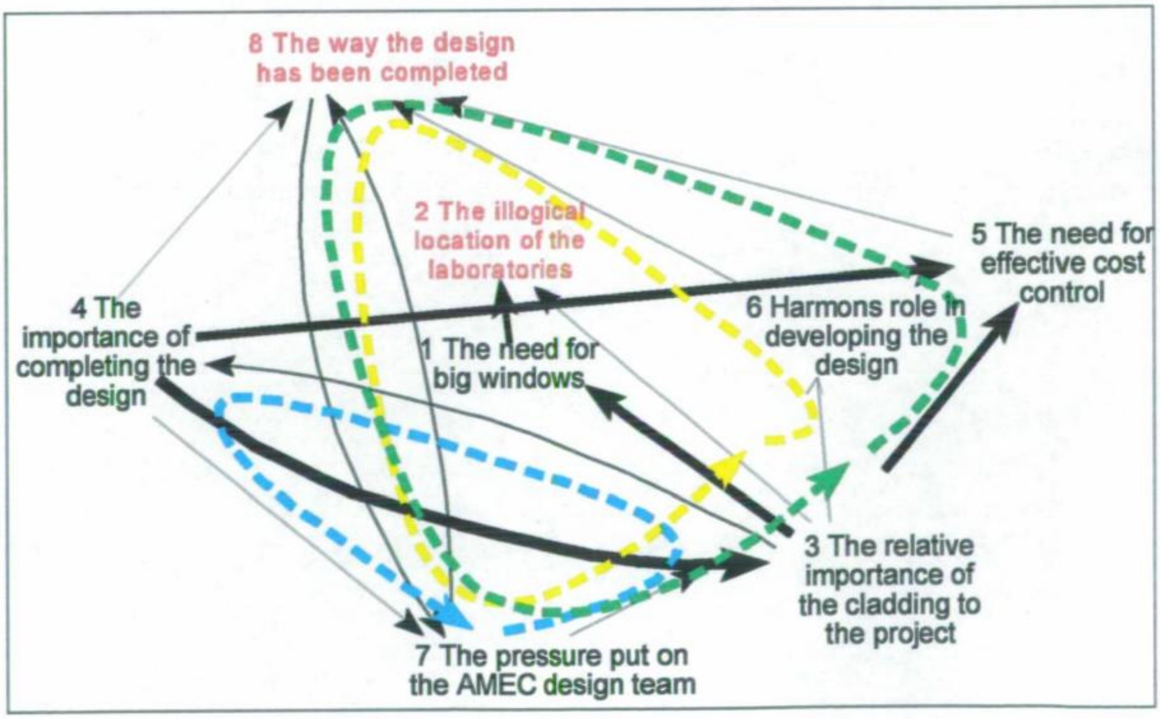


Figure 7.7 IJ Summary cognitive map

The results from the interview can be seen in figure 7.7 as being reasonably complex, with the appearance of several loops. The interesting features of the loops are that they confirm both the complexity of design management, covering issues of cost, quality of information and speed of progress, and the highly iterative nature of the process itself. An interesting observation was that the involvement of an individual from outside the direct area of the cladding introduces a different view which is more questioning of the basic logic. In this case the result is a fundamental questioning of the logic on which the space planning was based, and the direct implication of this decision on the cladding.

The existence of loops can possibly be explained by the 'umbrella' viewpoint taken, where issues relating to the way the whole design has been managed are taken into consideration and related back to the area of specific interest - the cladding. What is significant about the loops is the effect of various factors on the workload and time pressure placed on the AMEC design team. This pressure can be seen as an unanticipated influence on the way the design was both progressed and managed. When events unfolded in a way that was not expected and when those complications were persistent, the effect escalated upward and outward with ever widening consequences.

An interesting feature of IJ's map, and one that is not raised elsewhere, is the control of the design through the use of cost control measures. Cluster 5, The need for effective cost control, is strongly linked to both the importance of the cladding (cluster 3) and the importance of completing the design (cluster 4).

Examination of cluster 5 reveals that Project Design Notes could have been a strategic control device, but that their use has not featured in the control of the design of the cladding. This would imply that the situation involving HarmonCFEM either overshadowed the various PDNs raised in relation to the cladding, or that the design was altered without their use. The consequences of not using the PDNs was masked in the complex situation which then developed with the trade contractor.

g. MW, LMK Procurement Manager

MW was responsible for gathering the information from the various sources, coordinating it and arranging for the tender to be completed by suitable candidate companies. On the cladding parcel this was a complex task as the contract was significant in financial terms, the parcel was complicated and it was one of the first to be let. The tendering of the cladding was therefore a test of the quality of the information and the strategy for the procurement approach. MW's overall cognitive map (figure 7.8) indicates a core area related to the tendering of the trade contractor, as well as three separate issues (clusters 1-3), with a significant recommendation for early and strategic involvement of the trade contractor (clusters 2 & 3).

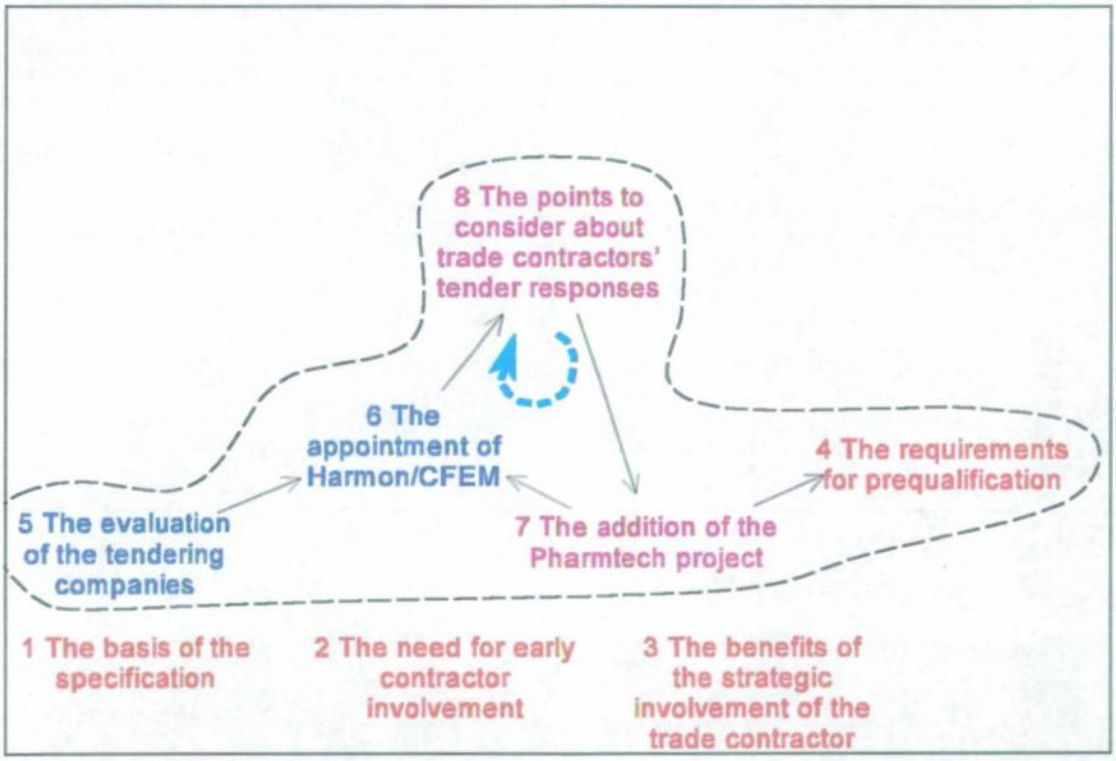


Figure 7.8 MW summary cognitive map

These recommendations are made independently and, although it is reasonable to assume they are linked, MW made a separate case for each. An examination of these clusters reveals that they were made on the basis of the current experience on the SC1 project, together with MW's experience on other complex projects. The advocacy of two stage tendering, which proved to be successful on the Stansted airport project, is not straightforward and is often considered as a complication which does not necessarily bring advantages of cost or time.

The bulk of MW's map concerns the importance of the scrutiny of the companies placed on the tender list. It would appear that the scope and depth of investigation of the candidate tendering companies, although appearing to be well considered, failed to inform the project of the potential problems which could occur, particularly when the size of the contract was increased. This is an important recommendation, for it demonstrates that although procedures based on previous experience may exist, and the procedures followed carefully, there is a need to continually reassess the information being transmitted, and to be able to adapt quickly to rapidly changing circumstances.

h. JI, LMK Shell and Core manager

JI would have been expected to have a significant involvement in the early stages of the cladding contract, providing an input at tender stage and then establishing the key objectives for the management of the construction. He was further responsible for ensuring that these objectives were incorporated into the design development period. As the contract with HarmonCFEM progressed, it became increasingly clear that there were significant problems. These problems were not limited to the lack of progress on the design, but were widespread and included the supply of key information necessary to plan the construction phase.

JI's map illustrates how complex the operation to appoint the trade contractor was. Two processes are identified in figure 7.9. The first, and smaller (1 & 2) relates to the initial issues associated with considering which company to appoint. From HarmonCFEM's initial performance at interview, which caused great concern, through to their appointment, a range of factors were incorporated - from allowance for their size, to the direct pressure placed by senior HarmonCFEM personnel on the senior project coalition managers to mitigate the affects of their poor performance. The result of the objective evaluation was subject to a number of other issues, and the inclusion of their influence made it a close decision. The dominance of commercial factors introduced at the end made the choice clear, but the implication on other areas, such as the likely effect on HarmonCFEM's workload for design could not have been fully investigated. The complexity of the two clusters explains the loop between them.

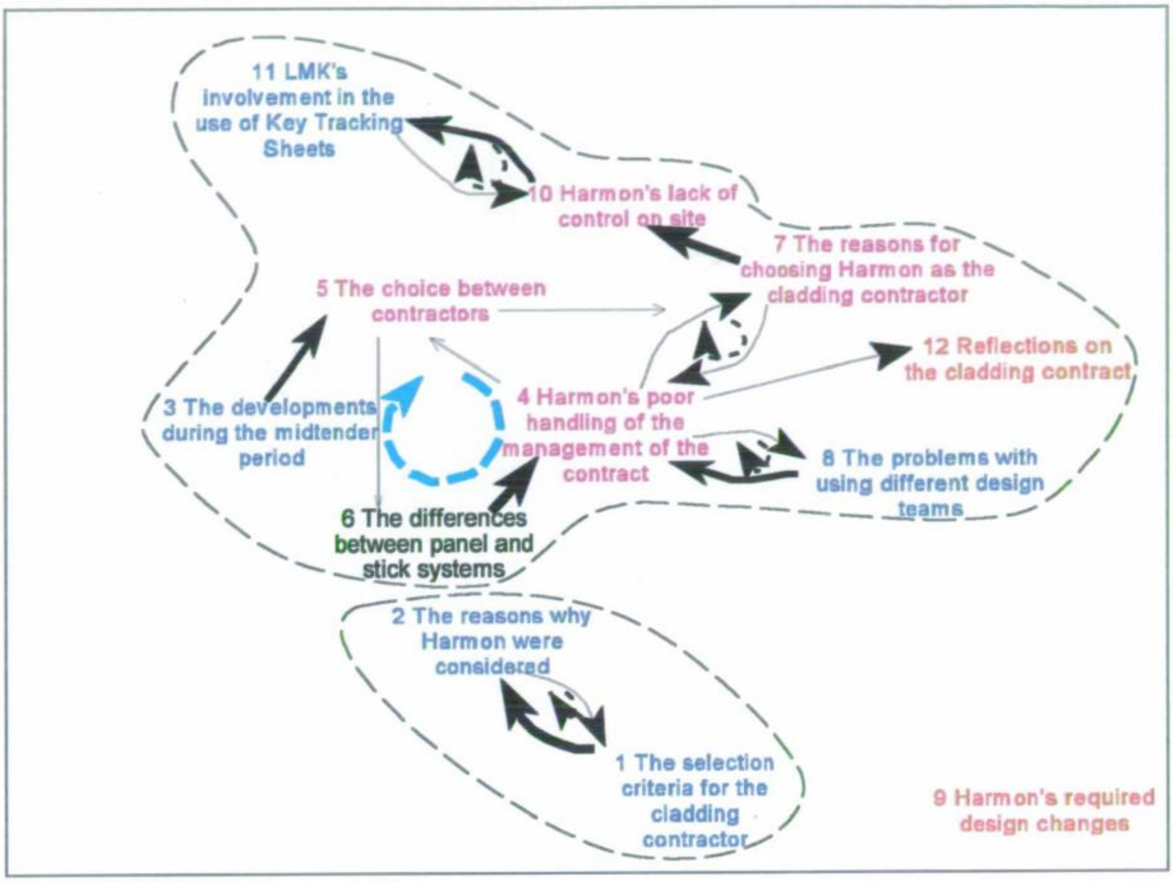


Figure 7.9 JI summary cognitive map

The second, and more complex process map, relates to the consequences of dealing with HarmonCFEM. Once on board, the line management reporting of the parcel manager made the problems quickly apparent with early intervention at a senior level. It is clear that the focus was on two distinct fronts, with JI primarily concerned with the construction related issues and the need for clear programmes for both installation and manufacture. By definition, this impacted on the design order, which was not integrated at that time. The result was to put additional pressure on HarmonCFEM, which was never originally envisaged.

As HarmonCFEM failed to respond to requests for information, JI became increasingly pro-active, eventually introducing a Key Tracking Sheet which substantially simplified the significant confusion which existed at the time. Without such constructive interference it is unlikely that the substantial problems would have been resolved as quickly.

i. DH, LMK Parcel Manager

DH became involved after HarmonCFEM were appointed and therefore inherited a situation which had been complicated by the addition of the Pharmtech project. The summary map (figure 7.10) shows how the issues relating to the detailed discussions on the complexity of the job are covered in the single cluster 'post tender period issues' (1).

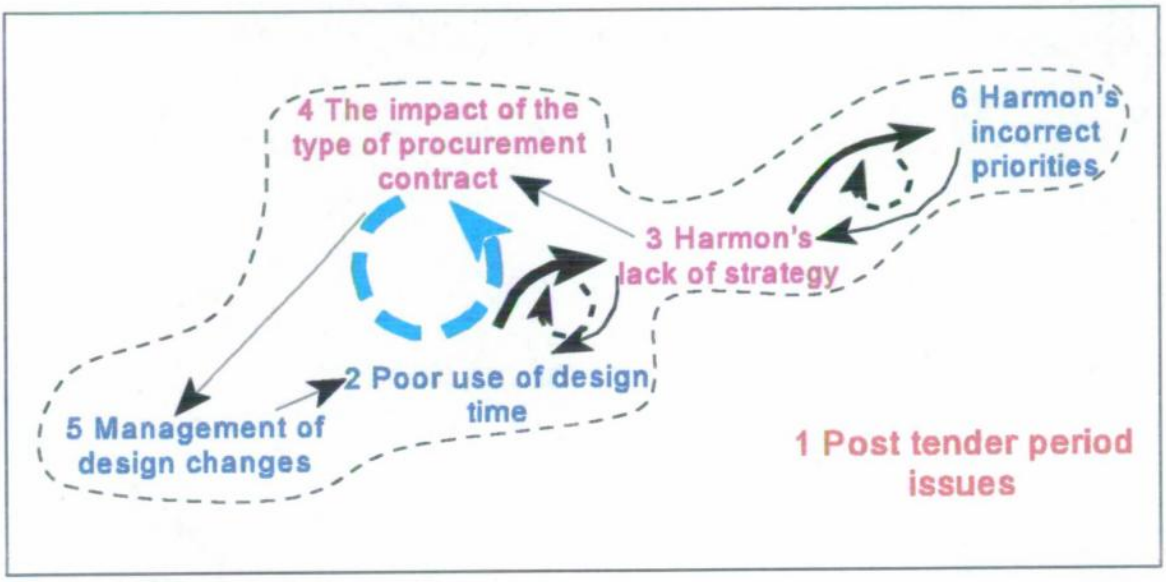


Figure 7.10 DH summary cognitive map

The remainder of the map, forming one process map, relates to the issues which were important during the contract. As the design progressed, so the issue of changing information became important. It was incumbent upon DH to manage the release of the new information to HarmonCFEM very carefully so as not inflame the situation. This element of the map, cluster 5, is linked in a loop with the impact of the procurement type (4) and the resultant importance of effective time planning and the need for a strategy from the trade contractor (2 & 3). The need for advance warning of significant changes was imperative as the relationship with HarmonCFEM was clearly under pressure and was likely to become adversarial, with the resultant arguments about areas of blame.

7.7 Conclusions of the analysis of the SC1 project

The SC1 project had benefitted to some degree from years of careful consideration, as SB wished to rationalise the UK operation in the SE of England and had planned for the relocation of departments and facilities. The opportunity to move to one site adjacent to an existing building at Harlow was an unexpected development, but one that clearly had advantages. Yet, with the long term potential gains in efficiency and effectiveness, there was a need to re-conceive the rationalisation for the project so as to provide a suitable single new building to replace the number of existing facilities.

The involvement of a US based master planner was quickly complemented with an experienced UK design firm. This provided the combination of world class design expertise with UK pragmatism and familiarity of specific regulations and requirements. Although this expertise was always going to focus on the complex interior fit out, the facility itself was a substantial building in terms of bulk and value. It also made a statement about the host organisation, which in the pharmaceutical industry in particular, is important.

From analysis of the data, it is clear that it was through the interaction of these factors, and for no other reason, that the concept for the design of the façade was selected and pursued. Although a substantial part of the overall project, the façade was seen only as a necessary element which enabled the more important internal features to operate in a controlled way. The previous experience of those professionals charged with responsibility for managing the façade led to the appointment of an external consultant, but there was a failure to clearly identify the role and responsibilities that this actor was to provide. This point may not have become apparent had the subsequent developments not been so unusual.

A fundamental problem area and one that has been found to be present on many projects, is the conflicting desire for rapid progress to completion, with a failure to handle risk satisfactorily. The result is a plan which culminates in the procurement of a trade contractor with a significant design responsibility which has fundamental contradictions built into it. The contradictory factors of price certainty, with flexibility of design solution and shortened deadlines, forces all the players involved to operate with little or no margin of error. Given that the highly complicated process being analysed is a fundamentally human process, any inherent problems in that process introduces potential problems which can easily overshadow the anticipated benefits from such multiple objectives. Examining the SC1 case, it is clear that such a situation developed. Two key factors occurred which took this potential risk and transformed it into the substantial problem which resulted.

The first was the late introduction of the additional work associated with the Pharmtech project. This project was not itself a late addition, but the decision to include it as part of the main cladding tender was, and this introduced substantial new risks. The additional pressure placed on the winning trade contractor was always likely to be great, particularly as the project managers were clear that the two projects would be treated independently, and would require two distinct responses. Given the 'blue skies' approach to the way the original concept design had been created, it was highly probable that, by the time the tendering process started, the proposed design was going to require adaptation so that it would be suitable for manufacture and installation by any of the competent companies who had been approached. It had been previously decided that the budget for the cladding would be based on the bare minimum necessary for the size and type of cladding proposed, but that this was an expectation not definitely confirmed by any contractor. The use of a clear and comprehensive set of specifications was seen as a satisfactory precaution to cover the client from risk. Yet the requirement for clear price certainty precludes the absolute clarity of design necessary and allows the possibility of future problems to arise from areas not fully detailed. If, to this classic situation you add a reduction in time to get the design to the stage where tendering can take place, and then add an additional commercially inspired desire for further reductions in tender prices, there is potential for significant problems.

The second area where the project was susceptible to avoidable problems was in the vetting of the final candidate companies. Although a substantial effort was made to ensure that the tendering companies were capable of meeting the challenges imposed by the contract, it would appear that the checks on the design and management resources were not sufficient. In particular, the failure to utilise the expertise available from the cladding consultant appears to have been a significant mistake, particularly as the project personnel responsible for appointing the consultant had correctly identified the need for a consultant with 'downstream' expertise who was familiar with the problems associated with complex cladding systems. It appears that evidence was available at the time of inspection that there were significant problems with the newly created HarmonCFEM and that the previous experience of dealing with Harmon would probably not be relevant.

The result of allowing such a combination of events, circumstances and attitudes to mix was the cause of great concern. Once an awareness of the potential problem was made, various members of the main project coalition expended significantly increased levels of effort and resource in order to resolve the problems. Despite a far greater involvement from both AMEC and LMK, the problems were not resolved. This allows a clear inference to be drawn, which is a powerful lesson. To resolve the problems caused by such circumstances is extremely difficult and, given the dynamic nature of the context in which the problem is located, practically impossible. Therefore, there is a strong argument for going to even greater lengths to establish the suitability of the expectations, project culture, and quality of the players, prior to embarking on the actual process which delivers the completed element. By carefully considering these points, there is more likelihood of being able to cope with circumstances as they develop, as they will be within expected boundaries. This consideration prior to starting can allow for areas of unknown information, parties not yet selected, or the likelihood of changing information, to be factored in to planned strategy for the management of the design.

The overall view of the management of the design at the SC1project is biased against the trade contractor. While it would appear that there is a strong justification for blame being laid with the trade contractor, and in particular the exceedingly poor way in which the HarmonCFEM senior management managed the project, the management of the design, from HarmonCFEM's viewpoint is missing. This is due to the client's concern with the ongoing problems and the way in which the situation was heading. Although this is a risk of studying active situations, it is a great shame that the overall picture could not be gained, and hence reduces the integrity of the data.

Chapter Eight
Refurbishment of the D10 Building for Boots PLC, Beeston, Nottinghamshire

8.1. Project Background

The D10 wets building in Beeston, Notts, was built for Boots in the late 1920s, specifically for use as a production building where liquid-based products would be mixed, filled, and packaged. It was designed by Owen Williams, one of the great modernist architects of the era, and an expert in flat slab concrete structure design. In addition to the atria and huge internal halls, the building's exterior is dominated by the large percentage of glazing, in the form of steel section floor to ceiling glazing produced by the Crittall Window Company. The building represents a giant example of modern architecture of the era, and was given a Grade 1 listing by the Department of the Environment during the 1970s in recognition of the importance of the building to the UK's architectural heritage. Throughout its history the D10 building has been continually used and adapted by Boots to meet its production requirements. This piecemeal adaptation of the building was carried out on a day-to-day basis attempting to solve immediate problems.

During the building's 70 years of operation it has continued to be used by Boots in much the way anticipated originally. During that period, the building's front elevation, which faces a large flood plain, has been worst affected by the predominantly westerly weather, with a resultant substantial deterioration in the in the window frames and damage to the concrete surrounds. In addition there had been many patchwork alterations and repairs carried out all over the façade resulting in a loss of the purity of the original design and a reasonably unattractive exterior.

8.2. The Establishment of the Project

In 1989, Boots decided that, because of the state of the building's exterior, and the move of a department from within the front of the building, it was a prudent time to plan a substantial refurbishment of the D10 building. Using Boots' internal estate management expertise, a 'broad brush' estimate was calculated for a project to upgrade the internal facilities at the front of the building and to rectify the many problems which existed with the front elevation.

Having decided that the cost was within acceptable limits, Boots Central Engineering Department began discussions with a number of multidisciplinary design practices, and selected BDP as the preferred company for the role of architect and engineer.

During the course of the exploratory discussions about the design options, it was clear that the statutory authorities were going to be important participants in the decisions made. The relevant authorities were the local planning authority and English Heritage. The planning authority boundary runs through the site, separating Nottingham City Council from Broxstow District Council. The D10 building fell under the jurisdiction of Broxstow District Council's planning authority. Preliminary discussions were opened with both the planners and the regional inspector from English Heritage, and involved both BDP and the Boots Central Engineering project manager for the D10 project. As the relatively small District Council's planning department was involved in the decision making process for one of the country's most important buildings of its type, the planning officers from Broxstow played a secondary supportive role to English Heritage, who were the lead representatives from the statutory authorities.

As the design intentions from Boots became clearly understood by BDP, and they began to work on design proposals, it became clear to Boots, that BDP was seeking to novate elements of the design to others. This was against the philosophy that Boots had developed which sought to achieve single point responsibility for all major projects. As the contractual differences continued, Boots began to explore the possibility of using other design companies capable of providing the service they wanted. After an extensive period of investigation, where over 40 design companies were contacted, AMEC Design and Management were selected.

AMEC were able to offer expertise in administering Design and Management contracts, had 3-400 designers, engineers, managers, and cost consultants, and the company had experience of process orientated facility design. By the time that AMEC was contacted, Boots had a clear idea of what they required, and had estimated the budget for the scheme at approximately £20m. Boots objectives for the project focused mainly on the relocation and upgrading of quality control laboratories, upgrading of services, and refurbishment of offices throughout the front portion of the building. The treatment of the exterior of the building had not been decided, as the discussions with English Heritage had not been fruitful.

AMEC's initial task was to prepare a scheme which could be approved by Boots and was capable of being submitted for planning permission. AMEC carried out surveys of the existing state of the building and the service installations, and discussed with Boots exactly what the functional departments required. While the interior requirements for the building were well established and easily communicated, the exterior of the building was more complex. It was clear to both Boots and AMEC that all the windows needed complete replacement as the design of the metal frames had allowed extensive rusting to take place, substantially weakening the structural integrity of the windows.

Boots employed the services of Gleeds as their cost consultant who checked all AMEC's submissions to ensure both the accuracy and thoroughness of the documents. Boots have a long standing relationship with Gleeds and are therefore able to focus on the management of the project rather than getting sidelined on purely financial issues.

As a Grade 1 listed building, no alterations could take place which, according to the relevant legislated guidelines, affected the 'character' of the building. The importance of the word character in the legislation which forms the framework for listed buildings, underpins the role of English Heritage. To obtain Listed Building Consent, English Heritage had to approve of the proposals, and the Planning Authority had to consent to planning approval. The proposed design changes for both the interior and exterior of the building were therefore scrutinised far more intensely than a new build project, with issues not normally encountered by the client and designer, being important.

8.3. The Players

a. The Client

Boots PLC are a major pharmaceutical company and the UK's largest retail chemist. Boots have a long and distinguished history which has always been centred around the city of

Nottingham. With a long history of in-house research and development and manufacture, the Beeston site, which forms the hub of their UK operations, is a large area which includes R&D, Production, power generation, incineration, and offices. Having built the site up over many decades, the portfolio of buildings on the site require a constant programme of maintenance and upgrading. To handle this work Boots have an in-house estate management department known as the Central Engineering Department. This department handle routine operations as well as acting as project managers for larger projects. Boots have an operational management setup which reflects different business specialities, and it was one of these, the product production unit, who were the client for the project. There is a clear distinction between the Boots client side and the project management side, with the former needing clear budget and timescale objectives to be met, and with the latter responsible for choosing the other project players, form of procurement, and ensuring the project meets its objectives. Once a project is sanctioned, the Central Engineering project manager becomes the focus for the project, channelling the information from the client side and being responsible for controlling the external project participants.

b. The Architect and Engineers and Construction Manager

AMEC Design & Manage Ltd. Are an integrated architect, engineering, cost consultant, and construction management company, which have gained a reputation for providing an integrated design approach for complex R&D, industrial, and production buildings. The large number of professional designers, covering all areas of architecture and engineering, together with construction management expertise, gives AMEC Design and Management a strong position where clients want single point responsibility coupled with a requirement for complex, functionally orientated, design. On the D10 project they act as designers and management contractors. In overall control was a project manager who had responsibility for both the design and construction.

c. Professional Quantity Surveyors

Boots PLC have a long standing relationship with Gleeds who perform all the cost monitoring and advising roles necessary on Boot's larger projects. On an integrated project such as D10 their role was initially to advise on the likely cost for the proposed project. As the project developed, Gleeds acted as Boots 'commercial policeman' and checked all of AMEC's monthly submissions and provided a monitoring and advisory service to ensure that budget forecasts were met.

d. English Heritage

As the agency responsible for ensuring that the nation's architectural heritage is ensured for future generations, English Heritage were seen as part of the decision making group from early on in the project life cycle. As the D10 project is a Grade 1 listed building and is well known by architectural historians as one of the most important examples of the modern architecture movement's industrial designs, it was expected that the role of English Heritage would be important. During the course of the D10 project English Heritage reorganised from a structure which distinguished between ancient monuments and ancient buildings, to a management structure based solely on geographical boundaries. English Heritage's operations are delegated to individual Inspectors who have significant power to interpret the guidelines according to their own perceptions. To provide a unifying control, there are layers of committees to which the Inspectors report when decisions or problems warrant.

e. The Planning Authority

The D10 building falls just within the boundary for the Broxstow District Council. As previously stated, this small Council did not have, at the time, the resources and experience to cope with all implications of such a prestigious project. The Planners were therefore happy to be treated as a partner to English Heritage, combining discussions on planning with those of maintaining the character of the building.

f. The Trade Contractor

Crittall Windows Ltd were responsible for the original glazing system installed on the D10 project which commenced in 1927. The same company were able to utilise the knowledge gained over many years to offer advice and technical expertise during the course of the extensive discussions which took place. Crittall were also able to offer access to the materials needed to provide a replacement system which are no longer widely used. Finally, Crittal offered modern quality control and assurance systems and the facilities to ensure that the components were manufactured in accordance with the strict requirements which the specifications demanded.

Figure 8.1 below illustrates the contractual relationships and main communication links between the parties discussed in this case study.

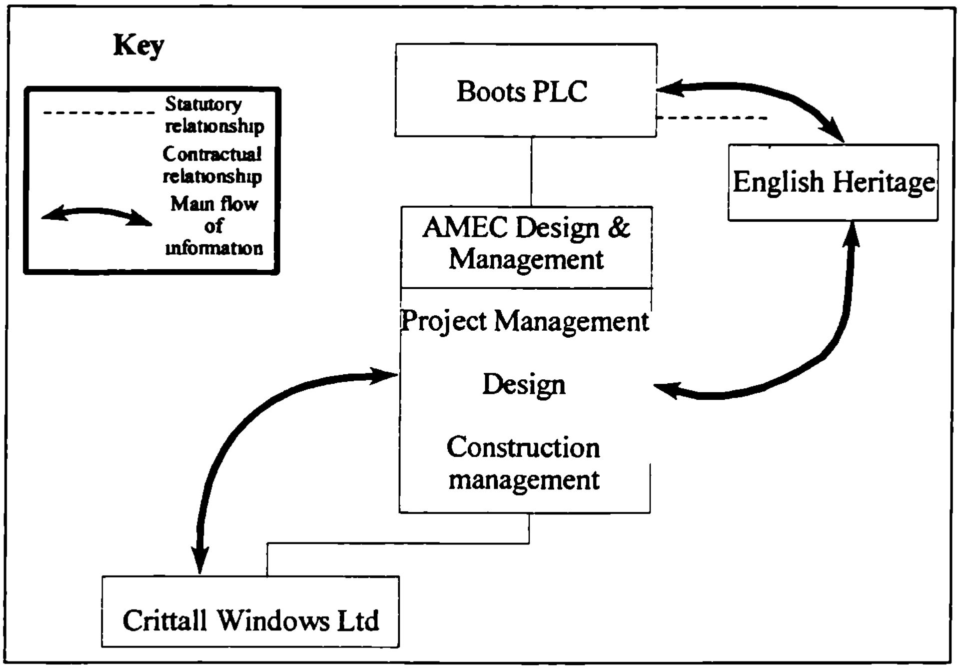


Figure 2.1 The relationships between the parties on the D10 project

8.4. The façade

Following the earlier discussions between Boots, BDP and English Heritage, AMEC's chief designer in conjunction with the Boots' project manager commenced discussions with English Heritage so that the decisions made on the requirements for the façade could be factored into the design development. The English Heritage Inspector had sought from his organisation additional back up from an English Heritage architect who was a keen supporter of the modern architect movement, of which Owen Williams was a part. The discussion on the façade's treatment was protracted and failed to progress despite a great effort put in by all sides. It became clear that there was a fundamental disagreement about what to do with the existing fenestration.

Boots and AMEC had previously decided that complete replacement was the only practical option but English Heritage wanted the retention of the original installation. Much time was then spent trying to agree a solution. AMEC carried out exploratory works to assess the viability of dismantling, repairing, and reinstating the original window frames, but this proved to be both practically and financially impossible. As Boots had stressed that the existing windows were failing to keep the weather out, English Heritage response was that a secondary glazing system could be installed which would act as a weather shield. This option was considered, but was expensive, lost valuable internal space and would not stop the original windows from continuing to deteriorate. As English Heritage were determined to preserve the existing installation, there were many discussions on the treatment of the façade. Once it became clear that the retention of the original façade was not possible, there was a lengthy period where little progress was made. AMEC made a number of proposals which were submitted to English Heritage for discussion. English Heritage's response was mainly to point out the faults in the submission and to require new proposals.

The design's progression on the façade was stalled for many months whilst this unproductive dialogue continued between AMEC, Boots, and English Heritage. There was a degree of anxiety and frustration felt by Boots and AMEC, but given the statutory power vested in English Heritage, there were few options open to them other than to attempt to persuade English Heritage of the merit of their proposed schemes.

In late 1991 English Heritage, as an organisation, was internally reorganised. Having previously been separated between responsibility for ancient buildings and monuments, English Heritage established its new demarcation based purely on regional geography, and reshuffled its existing personnel. A new inspector was appointed for the East Midlands, and he took over responsibility for the D10 project. The technical staff remained unaffected by the reorganisation, and so the new Inspector began working with the architectural advisor who had previously been working on the project. Having familiarised himself with the current circumstances, it became clear to the new Inspector that there was a need for rapid improvement in both the progress of the design for the façade and the relationship with Boots and AMEC. The Inspector established that, given the resources available to English

Heritage, there was little chance that they would be able to suggest a practicable scheme and therefore the emphasis need to be focused on working with AMEC and Boots on developing a scheme, proposed by AMEC, which met the guidelines.

As the D10 project was of national importance, the mechanisms existed within English Heritage for major decisions to be endorsed by its senior committee, and the Inspector decided that he would prepare a case for this committee to consider, based on the most current information. The evidence at the time was clearly in favour of replacement of the fenestration, and the committee was made aware of this outcome, given the protracted period of discussion and exploration of ideas. The committee's response was disappointment that such drastic action was being suggested but, given the situation, agreed that a replacement scheme was tolerable. There were however, a series of recommendations made, which basically required the replacement to be as similar in material and style to the original.

After receiving the new guidelines from English Heritage, AMEC explored the possibilities and found a number of complications with material availability. Contact with Crittall Ltd. revealed the original sections of metalwork which formed the window frames were no longer made. Having considered this fact, plus the requirements necessary to meet modern building standards, a search was then conducted to see what steel sections were currently made. This search was carried out by AMEC as the English Heritage representatives did not have the resources or expertise necessary to conduct a thorough search of all the material suppliers in the UK or Europe. As it was established that the replacement must be made from steel rather than the more popular aluminium, the choice set of suppliers was limited. Of the steel suppliers, Crittall made the closest modern equivalent under licence. One other UK company, Mellowes, was identified as having steel sections which were similar to the original.

Boots had made it clear that cost control was an important aspect of the project's requirements and that competitive tendering was to be used where possible. Even with the limited number of qualified companies in the specialised area of the cladding for D10, AMEC felt that it was necessary to ensure that there was adequate commercial competition. The added advantage of a competitive tender was seen as also providing an alternative design solution and therefore encouraged both companies to work on developing designs. A full set of tender documents were therefore prepared for both companies, and in addition, both companies were required to work on a design which would be installed as a mock up on site which would show the overall visual impression of their proposed scheme. As it was crucial that all parties, including English Heritage were supportive of the final scheme, the inspection of the samples was carried out by all interested parties, with English Heritage given priority. Both proposed schemes had their merits, with Mellowes major frame members being closer to the original than Crittall's, but with Crittall's scheme being closer in proportion to the original. AMEC also wanted to ensure that the selected company would be capable of producing the window components to a satisfactory quality and investigated the methods of production. Crittall demonstrated their superiority as they were able to galvanise large sections in house and then powder coat them, whereas Mellowes had to transport frame members around the country, between three locations to manufacture, galvanise, and then apply the paint finish. AMEC and Boots had proposed that the colour of the powder coating was matched to the dark green which was the original colour. This green had been covered by repainting in many different colours, on many occasions during the building's lifetime, culminating in white which was the colour of the fenestration before the refurbishment and when the building had been listed.

There were therefore three areas which were being compared; cost, aesthetics, and the quality of the product. Of these three the priority was for the aesthetic to be of prime importance, with the quality of the product second and cost last. The English Heritage inspector ensured that the final decision was made by the same committee who had been approached previously. It was clear that the English Heritage representatives who saw the two schemes preferred the Crittall design and that Crittall had the better setup for ensuring consistent quality. When both companies returned the tenders there was little difference in the prices submitted, making the choice of Crittall straightforward.

Crittall then proceeded to work with AMEC to develop the full design. During the course of this work, Crittall undertook a full survey of the existing structure and found that there was a substantial variation in building tolerances on the existing structure. The structure varied locally with variations in cill and head height of up to 50mm. In addition the whole building dropped from one side to the other by 50mm. This considerable variation in structural tolerances required a carefully considered design response. If the new design were to follow the original it would vary with the structure. This was considered unacceptable, as aesthetically it would have looked uneven. The preferred solution was for a floating head fixing with a cover which could mask the variation at head height. At cill level, the solution to the variation was proposed by Crittall and involved a cill cover. Both these additions to the original impaired the original sight lines but were felt necessary to provide the new installation with the clean lines which were considered visually important.

This work was carried out without a contract being signed, as Listed Building Consent and Planning Permission had yet to be given. As the applicant can submit backup evidence for both submissions, Boots and AMEC commissioned a professional video to be made outlining all the important points. Although not present at the hearing of the application for Listed Building Consent, the English Heritage inspector showed the video and when considered in conjunction with the other information, granted Listed Building Consent. As this decision is closely linked to Planning issues, and following the participation of the planning officers during the course of the meetings between English Heritage and AMEC, Planning Permission was also granted.

Once the statutory authorities had approved the proposed scheme, the actual project could commence in earnest. By the time manufacturing began, the design had been considered for many months and there were few problems. There were some problems associated with the powder coating of the first items to be manufactured, particularly with bubbling at the bottom of the main mullions, but AMEC's strict quality assurance procedures rejected these before they were installed, and Crittall was able to resolve the problem.

The most significant problems were associated with the sequencing of work. Two particular problems were the cause of concern. First, the requirement to work in a building which was still occupied was not fully considered. In the majority of areas the policy of decanting the resident department and personnel worked well. There was however, one section where for reasons which did not appear to be fully justifiable, a sensitive drug mixing unit did not move during the installation of the windows. As these two operations were not compatible, there was a need for Crittall to install robust, high quality screening. This 'temporary' construction was time consuming, expensive and was not indicated as a requirement during the tender stage.

The other issue was the ordering of activities between different trade contractors. Within this area, two distinct problems were identified. First, there were demolition activities taking place in areas where the new windows had been installed. The potential for damage was high, and although protection clauses were included as part of the contract, the disruption caused by the need for rectification or replacement of new windows would have been great.

Secondly, the form of contract used made each trade responsible for its own access requirements. On the exterior, Crittall was working on a horizontal basis, whilst Cement Gun, who were carrying out concrete repairs, were operating on a vertical basis. This resulted in both parties working in the same area, but with Crittall working off a scaffold, whilst Cement Gun worked from cradles. Such repetition was ultimately inefficient, as one universal form of access, probably scaffold, would have met both companies needs at a lower overall cost.

8.5. Completion of the project

The result of the project was for the installation of a new set of double glazed windows, which together with the concrete repairs, effectively gave the building a new façade. Internally, the building has been modernised, with new laboratories, including 30 new fume cupboards, new services, and upgraded offices. The project has achieved much success, with Boots achieving its functional objectives of relocating key departments, upgrading facilities, and expanding the office space available. Externally, the new façade has reinstated the dramatic scale and splendour which the original Owen Williams design was famous for, whilst at the same time providing far superior protection from the weather, and providing a more controllable internal environment.

8.6. Analysis of the cognitive maps on the D10 project façade

a. JB, Boots PLC, Senior Project Manager

JB was responsible for developing the client brief on behalf of the Boots client, the Contract Manufacturing Department and, to the external project players forming the project coalition, JB was the client representative. As an employee with many years experience with Boots, ranging from production through to project management, JB has a wealth of experience of Boots operational requirements and procedures, the best suited forms of contract for employing external construction companies and a general knowledge of technical construction issues.

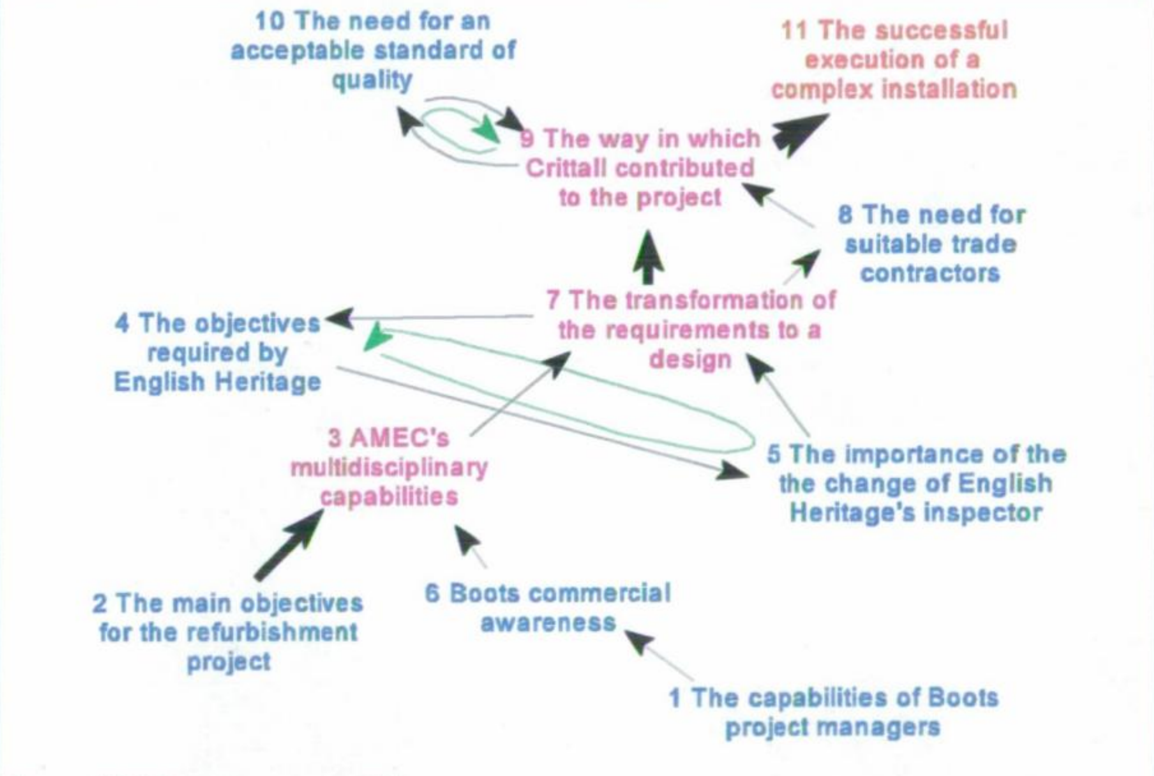


Figure 2.2 JB summary cognitive map

The summary cognitive map illustrated in figure 8.2 demonstrates how, from the client's viewpoint, the project was set up correctly from the outset, using AMEC's multidisciplinary skill (cluster 3). One of the most interesting features of this map is the loop between clusters 4, 5 and 7). This loop represents the period of time spent in discussion with English Heritage where, because of the power vested in each of its inspectors, there was a particularly unproductive dialogue during which AMEC and Boots would propose various design solutions, only to have the proposals rejected on the basis of English Heritage's requirements (cluster 4). The breakthrough came when the English Heritage inspector was changed and the new individual recognised the effort and time spent by Boots and AMEC on attempting to create a design solution for the façade which met Boots performance and technical requirements, as well as preserve the important design style created by Owen Williams. With this new individual in place, achieving Listed Building Consent and Planning approval were more easily achieved. As the requirements for the scheme were, by the time of planning approval, reasonably clear, it was a high degree of confidence that the appointment of the trade contractor was considered. It was always probable that Crittall would play a significant part, ultimately resulting in their appointment. With Crittall on board the design progressed with Crittal playing a very important role in ensuring that English Heritage's requirements were met in detail, whilst ensuring that the scheme was capable of being manufactured in a commercial environment. The second small loop between clusters 9 and 10 illustrate how the specific issue of the quality of the product is the result of negotiation, invoking either positive suggestion or negative criticism. The ultimate result of this complex project process was, in terms of the client, a satisfactory outcome with the project being completed within the agreed budget and delivering a building which met the functional requirements of the client whilst vastly improving the aesthetic appearance of the building and extending its useful life.

b. CD, Project Manager, AMEC Design and Management

CD was appointed project manager for the D10 project initially to manage the design stages. As the project entered into the period of discussion with English Heritage, so it became clear that there would be a greater role for managing the decision making stage involving the statutory authorities. CD continued with the project until handover and was actively involved in managing AMEC's input into the project, which included managing the involvement of Crittall. The summary map show in figure 8.3 illustrates the complexity of the AMEC involvement.

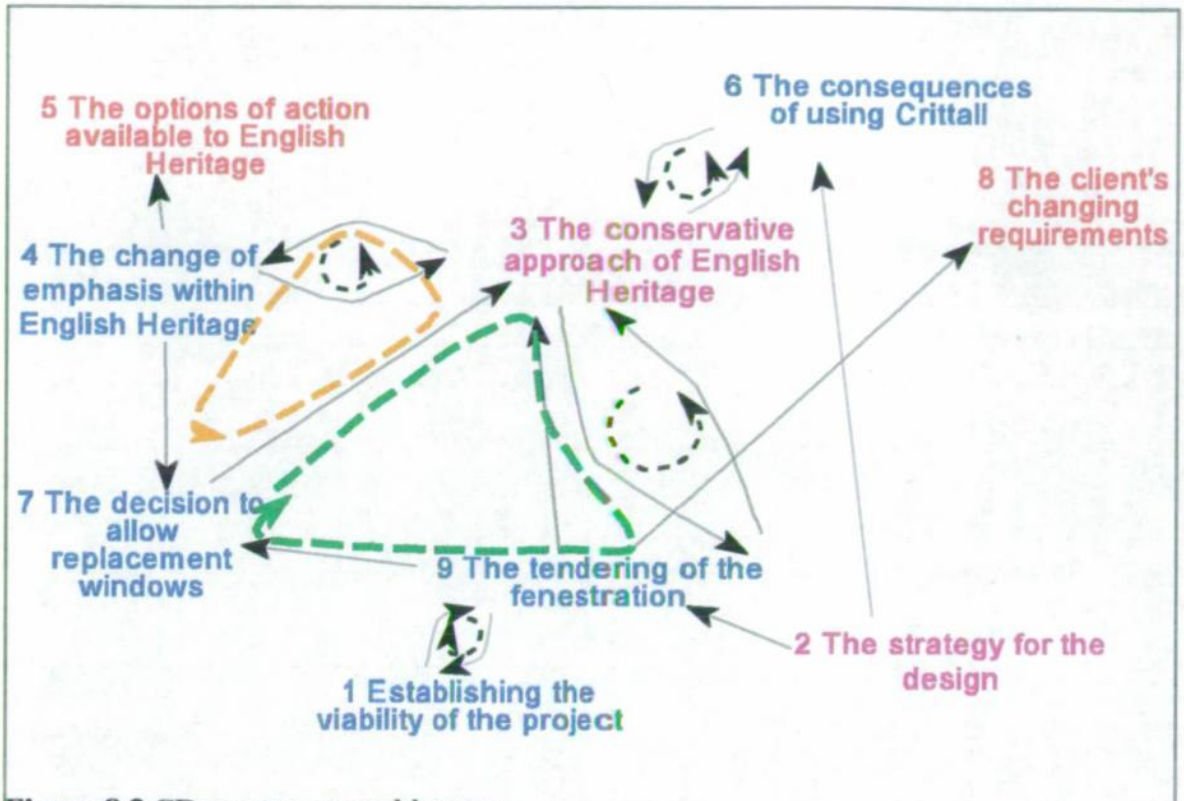


Figure 8.3 CD summary cognitive map

The summary map shown if figure 8.3 has a number of loops which represent a number of issues. The key to the majority of the loops is the involvement of English Heritage and, in particular, the debate regarding the question of whether to repair the existing windows or to replace them. This protracted period of discussion was only broken by the introduction of a new inspector (see appendix 3b, cluster 4, concept 84). With this new individual came a different view of the context of the problem. The new inspector, NB, was aware of the potential power that Boots, as a major UK company, could wield in the political arena. This new approach enabled the project to progress, introducing the involvement of Crittall Windows Ltd. This was related to the strategy which AMEC and Boots had formulated, but which had been significantly adapted by the complication of dealing with English Heritage. As the activities of English Heritage affected the way in which Crittall were operating, there was an iterative process between Crittall and the work of English Heritage (clusters 3 and 6).

c. JS, senior architect, AMEC Design and Manage

JS was in overall charge of the design for the D10 project with a team of designers working under his authority on individual elements of the project. Although an AMEC architect was directly responsible for the design of the façade, it was JS and latterly the AMEC Project Manager who were primarily responsible for the key decision making on the façade's design during the key stages of design development with English Heritage.

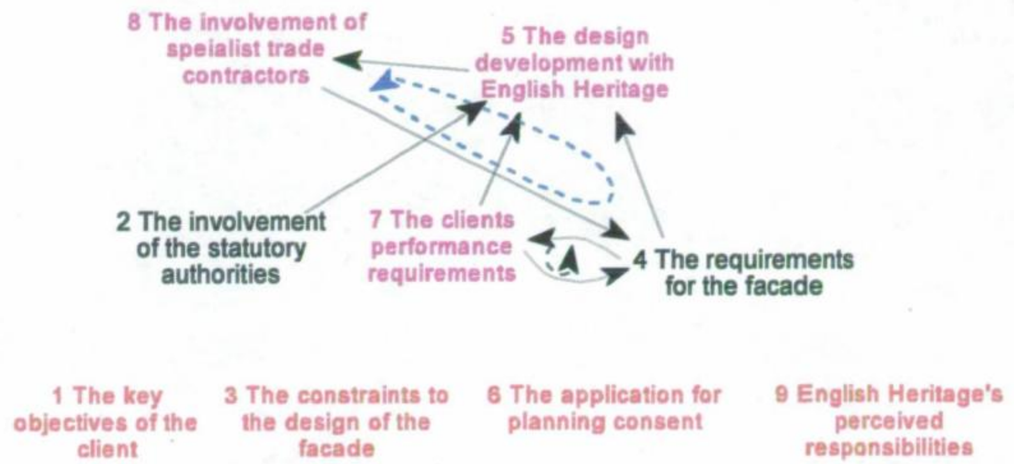


Figure 8.4 JS Summary Map

Figure 8.4 above separates the core issues of the design development process from those separate issues which, although important, are not directly related to the main issues. Again the main issues arising from this map are the requirements for both the project in general and the façade in particular, the role of the statutory authorities and the involvement of specialist trade contractors. The largest loop found in figure 8.4 links client requirements with the design input of both the trade contractors and English Heritage. The smaller loop shows the iteration between the requirements for the project and that of the façade.

d. NB, Regional Inspector, English Heritage

NB was the replacement Inspector for English Heritage and inherited a case which was becoming increasingly fraught. As each English Heritage Inspector has the personal responsibility to manage the case according to their individual understanding of the issues and context, NB quickly appreciated the potential scale of the dispute which was looming. The summary map shown in figure 8.5 illustrates how NB interpreted the events.

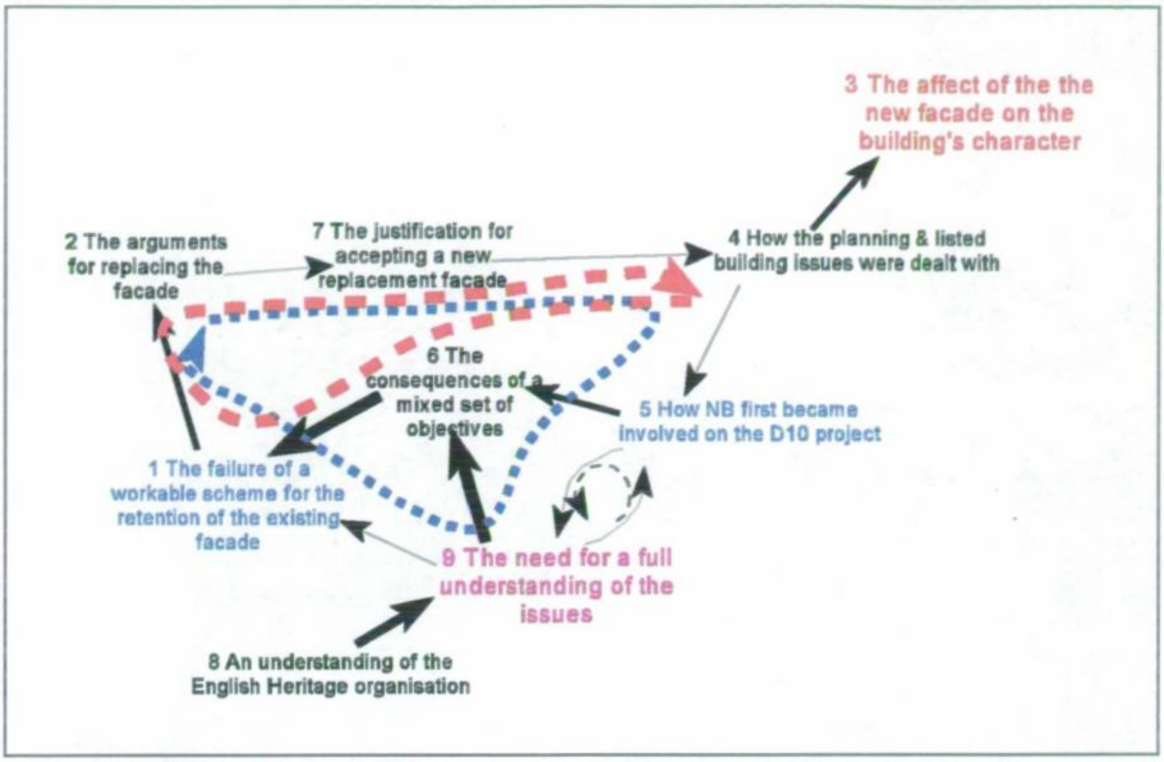


Figure 8.5 NB summary cognitive map

The integrated map shown in figure 8.5 demonstrates how the background of both the organisation and the individual concerned are important factors in influencing events. The core of the map, including the two main loops, deal with the complexity of issues related to developing a coherent scheme which met the various, and potentially conflicting, set of objectives which the key parties had. Having explored the issues and proposed alternative solutions, the decision to proceed with a replacement scheme was considered by the planning committee, which was itself a key consideration for NB when he became responsible. Ultimately the main concern of NB, as demonstrated by cluster 3, was the affect of the façade's design on the character of the building, which was the prime concern of English Heritage.

e. RW, UK Site Operations Manager, Crittall Window Ltd.

RW has a long employment history with Crittall and combines both design and site management skills. As head of the Crittall operations on the D10 project, RW was involved at a relatively early stage in the design development, as AMEC were seeking the advice of competent contractors about the availability of specialist materials. From these initial discussions, RW was actively involved in all aspects of the D10 façade, overseeing the design development, conducting contractual discussions and orchestrating the site operations. RW's summary map is given in figure 8.6.

RW's summary map shown above provides an insight not present in the other cognitive maps,

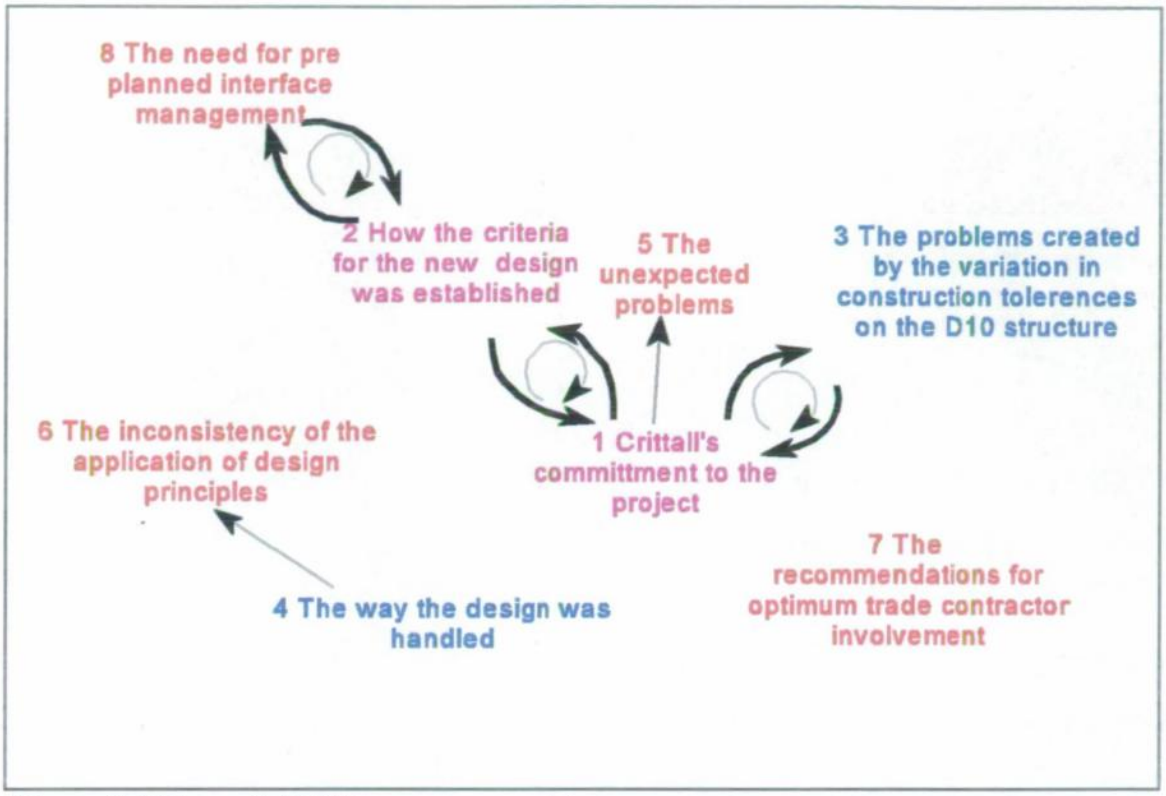


Figure 2.6 Figure 8.6 RW summary cognitive map

namely the identification of an inconsistency of the application of the design principles. This perception appears to be explained by the approach taken by AMEC, Boots and English Heritage which grappled with the overall design principles and which appeared to allow the 'special' areas to receive less attention. This lack of consistency was a possible sacrifice in order to progress the project in a reasonable time, given the protracted period of discussion on the early general design principles.

8.7. Conclusions of the analysis of the D10 project

The Boots D10 'wets' factory refurbishment project contained many of the factors which would define the project as complex. The phased refurbishment of an occupied and functioning building which was Grade 1 listed posed a significant project management problem. The direct contradiction between a client need for up-to-date facilities and internal environments and English Heritage's prime concern of preserving the building's character needed careful and considered management. The project players, from Boots and initially BDP and then AMEC, sought to open a dialogue with the statutory authorities at an early stage. The reticence of the English Heritage architectural advisor to shift from a position of preserving the original façade caused increasing concern and a significant amount of fruitless work to be carried out. If there had not been a change of English Heritage Inspector, who chose to not follow the advice of his own advisor, the conclusion to the D10 project would have been significantly different. The attitude of both Boots and AMEC were that English Heritage's initial intransigence would have eventually forced them to a Public Enquiry which would have increased the political profile of English Heritage in a potentially unfavourable way. The fortuitous change of English Heritage Inspector gave a new lease of life to the project and managed to re-motivate the dejected project players. The result was a rapid advancement in the design which, by this stage, included the specialist contribution from Crittall Ltd. This design stage, significantly longer than anticipated, did have significant advantages for the project as, with so much time and resource devoted to exploring all potential solutions, the final design solution was extremely well considered and incorporated features which managed to combine a respect for the original design, modern performance specifications and was capable of being installed in a structure with an extreme range of existing tolerances.

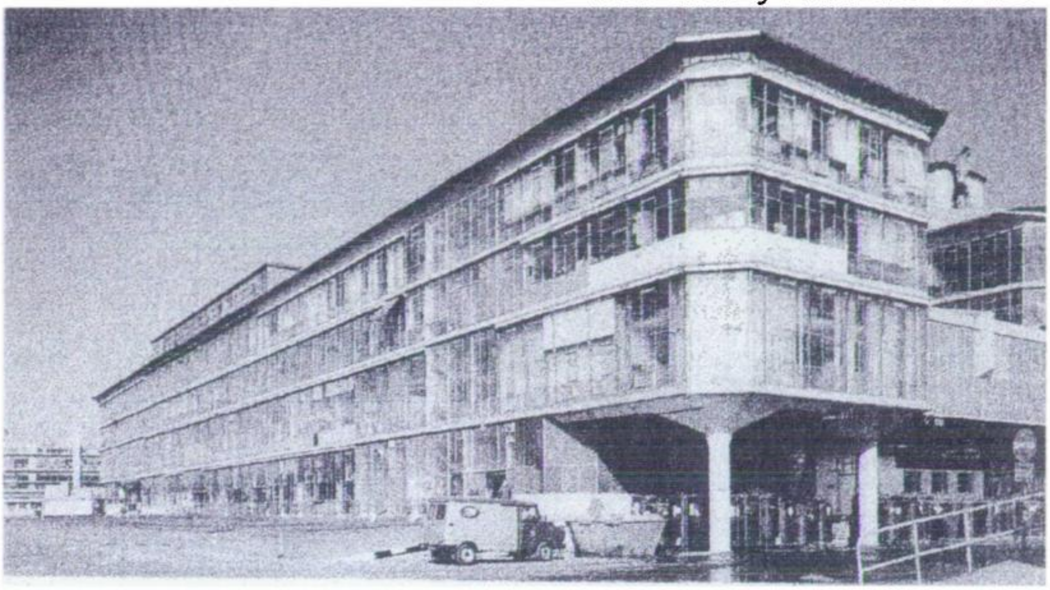
Although there were problems on the project, they can be classified as secondary compared to the degree of success which the project achieved. The problems, interestingly, were primarily linked to the lack of consideration given to certain aspects of coordination. Given that the design development forced the project parties to work together on certain aspects, it is a point worthy of reflection that establishing the details of site activities, phased access and details of the specifications were not handled in a similar way. The explanation for this is that with a limited management resource, the need to prioritise is paramount, and certain aspects of detail information, site coordination and establishing effective communication links between project players were not fully considered. Given the scale of the problem facing the project coalition this criticism has to placed in the context of a project which has been generally hailed as a sympathetic and well considered refurbishment, which the client is pleased with and which came in under budget and did not force the commercial sacrifice of any of the project players.

The building was awarded the Europa Nostra award for its refurbishment in 1995, the industrial building category National Building Awards, RIBA 1996, the conservation category winner and short listed for the Stirling Prize for Architecture, 1996. The judges described the project as 'An impressive job, beautifully executed'. (Guardian, 8th November 1996, p.11).

Figure 8.6 on the following page is a comparison photograph of the building taken during the early 1960s and after the refurbishment.

The refurbishment of the Boots 'Wets' factory

The D10 Wets factory in the mid 1960s



The D10 building after refurbishment mid 1990s

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Chapter Nine
The Helicon Project
Finsbury Pavement, London

9.1 Project Background

The Helicon building is a speculative development occupying a prominent island site on the northern limit of the City of London, close to Moorgate. The development comprises retail space on the lower floors together with high quality office accommodation on the upper floors. The retail space was pre-let to Marks and Spencer PLC whilst the office space remained unlet throughout the construction period of the shell and core. The project was let as an adapted traditional JCT 81 form of contract and was due for completion by the end of 1996.

The project has been developed by a developer who previously owned a significant proportion of the island site during the 1980s. Having failed to gain planning consent for an earlier redevelopment scheme, the site was sold in the late 1980s, which in hindsight was the height of the London property boom. The new owners of the site were not able to redevelop the site, due to the major downturn in property prices following the recession of 1989-90. The site was offered for sale and, by this stage, was offered as a complete island site. The developer who had previously sold the site re-acquired it. One of the main reasons for this commercial decision was that the developer were aware of the interest of Marks and Spencer, who wished to exploit the success of the small retail store which they operated very close to the site. The existing Marks and Spencer store was one of their most profitable, but due to its small size, was not able to carry a wide selection of produce and merchandise. This existing store was the only Marks and Spencer store in the City of London, and so the potential clientele was very significant. The developer acquired the site whilst at the same time discussing with Marks and Spencer the possibilities of arranging a long term lease arrangement. These negotiations were successful and the developer ended this period with a valuable site and a blue chip core tenant signed up.

Having established a core tenant, the developer was aware that the Planning Authority would not permit a low rise building used solely for retailing in the proximity of such an established area and therefore was clear that the new building would be a mixed development with the retail space on the lower floors and office space above. The developer preferred to use an architectural practice which they had previously worked with and after considering practices with whom they were familiar, entered into direct discussions with Sheppard Robson about the design for the new building. The developer was aware that the site was prominent and sought to have a building with a high degree of aesthetic quality as well as meeting other performance and functional requirements. Given the timing of the project, at a time when speculative development in the commercial sector was at its quietest for many years, and when office rents in London were depressed, with large quantities of vacant space available, there was significant pressure to make sure the project was a success. The important features for the project were therefore to provide offices for which there was likely to be a demand. The key features for such an office, according to market analysis, were flexibility of use, pleasant spaces which were cheap to maintain and run. The office space was going to have to be located within an outstanding structure, both reflecting the prominent location of the site and the implied reputation which any occupier would gain from the external appearance.

The responsibility for the project from the client company lay very clearly with the project director who was able to strongly influence the style of the design from an early stage. The freedom to exploit a range of different design solutions for the appearance of the building was available because the site fell on the boundary of the Islington Borough Council. This Borough of London has a less stringent approach to the appearance of buildings, unlike the City of London, who prefer to enforce strict guidelines to maintain a unified image for their street scapes. The discussions with the architect initially started with a conservative brick built design. The transfer of the project to another of the design studios within the practice led to a change in perception of requirements and discussions then quickly focussed on a modern steel and glass building. As the design progressed, the discussions with the Planning Authority were problematic as the Planning Authority's view were that the proposed scheme was following a trend of increasing the bulk and size for proposed redevelopment projects. By the time the project's design was capable of being sent for Planning Approval, the proposed scheme was approaching the maximum bulk permitted by the planning guidelines and local bye laws. At the meeting of Islington Borough's Planning sub-committee, the Chief

Planning Officer opposed the development because of its bulk. The sub-committee chose, for reasons associated with other social and political issues, particularly the creation of local jobs, to ignore this advice and granted the scheme planning permission.

9.2 The Players

a. The Client

London and Manchester Assurance are a small financial investment company whose base is Exeter, Devon. The Helicon project was a considerably larger development than their normal scale of investment in property and hence posed a potentially high risk for them. The Director of Property for L&M was given virtually total responsibility for deciding how the project progressed. As a small company, communication lines were short and direct, but these were of secondary importance, given the hands on involvement of the Project Director.

b. The Architect

Sheppard Robson are an established London based Architectural practice who have worked on a range of building types during their existence. With a reputation as a practice with a wide skill base, focusing on projects which are innovative, yet not fantastic, Sheppard Robson deliver designs which satisfy the client's functional requirements. Within the practice, there are a number of quasi-autonomous design studios, headed by partners, who work on projects independently. These studios concentrate on different types of building, style, or design speciality, drawing on central design expertise in specialist areas when necessary. GA was the lead architect within one of the studios who has a passion for modern steel and glass buildings. For the façade, GA was assisted by an assistant in the production of details and handling day-to-day design queries.

c. Professional Quantity Surveyors

Silk and Frazier Ltd have worked with London and Manchester for many years and provide full cost consultancy services, from advice and forecasting to preparation of Bills of Quantities and validation of claims. On the Helicon project Silk and Frazier were actively involved in monitoring the design progress to ensure that the client was aware of the likely financial impact of decisions taken on the design. Their services continued through the construction phase where they monitored the contractual developments and made recommendations to the client on submitted claims.

d. Services Engineers

Ove Arup and Partners were employed by London and Manchester to provide services design. In addition Sheppard Robson persuaded L&M that Ove Arup were required to provide specialist advice on the structural requirements for the façade's most dramatic feature, which is the suspended curved glass SW corner and which forms the main entrance to the offices.

e. The Main Contractor

Laing London, the regional division covering the metropolitan area of London and its environs, were chosen to be the main contractor under an adapted JCT 81 form of contract.

f. The Trade Contractor

Scheldebauw are a Dutch cladding contractor who were bought by Permastelesa, in 1992. Scheldebauw are a medium sized contractor in the international arena of cladding contractors, but as they are capable of handling highly complex façade designs and are continually increasing and improving their manufacturing capabilities, they are an increasingly important player in the NW Europe sector.

Figure 9.1 below indicates the relationships between the parties involved on this case study

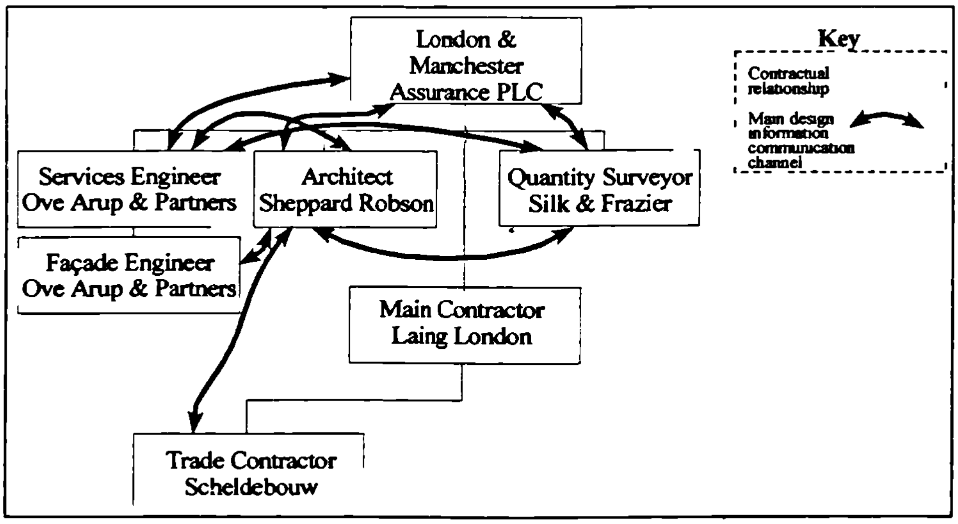


Figure 1 Relationships between the key players for the façade on the Helicon

9.3 The façade

The design of the façade was one of the most important elements of the building. The façade of the Helicon had to achieve two primary objectives. Firstly, it had to create the correct impression for the building. This was both as a statement of architectural design, which the client was keen on and as leading edge engineering. As a building which made a bold statement about its design, whether this statement was perceived positively or negatively, was felt to be preferable to a run-of-the-mill 'safe' design. Secondly, the building's façade had to be thermally efficient, as one of the performance requirements was that the building should be both pleasant to work in and cheap to run. This particular requirement created a complex design problem as the architect wanted a primarily glass façade, but as the site is an island bounded by roads, there were problems of solar gain and traffic noise. As a separate, but related issue, the client was convinced by Ove Arup of the benefits of passive air conditioning, in the form of chilled ceilings, which have not been widely used in the UK. The significant benefits of this form of internal climate control, in terms of noise, even distribution of air and running and maintenance costs, require a relatively limited range of external conditions. To control the extremes of hot and cold, the façade was utilised as a primary buffer. The result was that the façade was triple glazed, with a standard double glazed unit then a 900mm buffer air plenum and finally a single glazed external skin. The plenum acted as a static air buffer in cold weather and a moving air chamber in summer with the provision of opening vents at the top and bottom of the building. To control the problems of solar gain and internal glare, a new form of blind was developed by a specialist company (Technical Blinds) which operates like a Venetian blind, but with 400mm wide blades. The use of blinds was seen as preferable to any form of reflective or tinted glass, which the architect was strongly opposed to. The glass does have a mild tint which is the result of a thermal coating used to reflect heat. As the design developed, the architect was keen to employ a suitably qualified contractor who was capable of manufacturing and installing what was clearly becoming a very complex façade.

The selection process was potentially complicated by the use of a traditional form of contract, administered by Laing London, part of John Laing PLC. This form of contract benefits from clear cut contractual relationships, normally made by the main contractor on a cost basis. The introduction of a complex element of the building which, by its very nature, needs to be developed by the architect and the specialist contractor, introduces many issues which the traditional form of contract, in its simplest form, has difficulty coping with.

The architect for the Helicon did have a clear preference for the contractor that he had experience of working with. A formal tender process was carried out which established that the preferred contractor (Scheldebauw) was no more expensive than the other comparable companies and, as they had worked with the architect on a previous project (one of the Glaxo campus buildings), which was seen as a successful project, Laing had no objections to their appointment and accepted them as a standard sub contractor.

The detailed design development took place over a 9 month period, building up to the construction, and subsequent testing, of full scale mock-ups. By this time there were 13 distinct façade types, all requiring different design or manufacturing processes. Throughout the design development the Planning Authority was kept fully informed of developments and the Chief Planning Officer, who had originally opposed the project, was invited to attend the tests of the façade in Holland where the contractor was based. The rolling schedule of tests was likely to be the most difficult stage to pass, as there was no way of predicting how a novel design would perform when subjected to the formal requirements of water and air pressure tests. This stage also provided an extremely useful opportunity to see how the proposed designs looked at full size and incorporate the comments into the main manufacture stage. This stage went remarkably well, to the very pleasant surprise of all concerned. The only element which failed the test; a sliding door, was due to the onerous test specifications imposed which were far higher than normal. Once this particular issue was resolved, the tests were completed satisfactorily.

Having completed this key stage in the design, the façade went into manufacture with virtually all the details resolved. There were some problems related to the separate testing of the blinds which were found to oscillate due to the draught created by the movement of air throughout the plenum. This resulted in the need for guide wires, which subsequently forced the façade design to alter, removing mesh grille walkways. The other major alteration was the result of the prevaricating of Marks and Spencer over the inclusion, or exclusion, of an atria covering a coffee shop area. This one item was altered a number of times, finally being included, but after such a delay that the design, manufacture and installation were problematical.

9.4 Analysis of the cognitive maps on the Helicon project façade

a. DL, Property Director, London & Manchester Assurance

DL, the individual charged with the responsibility of completing the Helicon project maintained a strategic position on the development of the project, whilst making operational decisions where necessary.

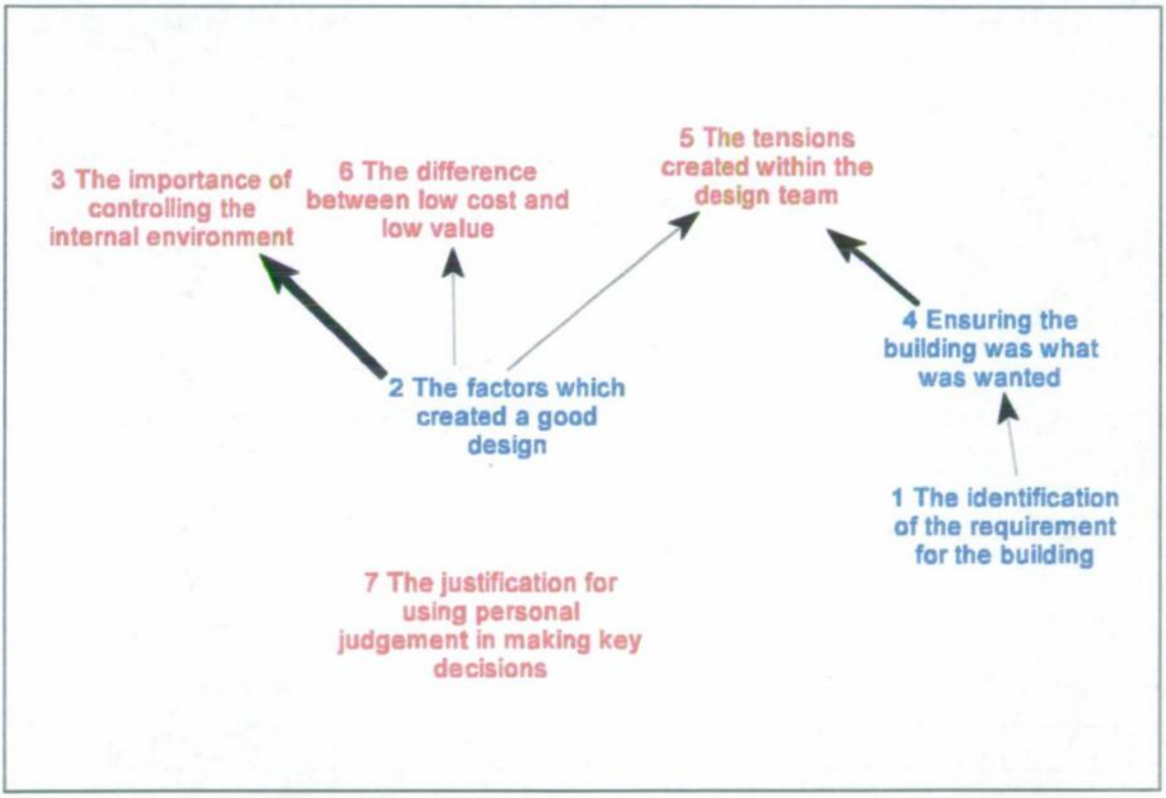


Figure 2 DL summary cognitive map

The summary map shown in figure 9.2 captures all the important aspects of the project, ranging from cluster 7, the justification for using personal judgement for key decisions, through to the recognised importance of controlling the internal environment. One of the most important aspects of the summary map is the identification of the tensions within the team. This issue particularly concerned the fraught relationship between the architect and the

PQS. The tension resulted from establishing a good design and having a number of objectives for the building. As the PQS was actively involved in monitoring the design during the course of its development, the decisions as to what was acceptable as proposed design solutions, only occurred after discussions involving direct challenges from the PQS on the need for certain design features. The result was a building that offered both a controlled internal environment and high value. The cost of these benefits was the deterioration of the relationship between two members of the project team. As the individuals involved were professionals, it was not readily identifiable that there was a problem. The consequence was that there was no intervention to resolve the problems. The effect of this breakdown of relationship did not, however, negatively affect the project.

b. GA, Project Architect, Sheppard Robson

GA was the principal creative force behind the whole Helicon project. As such he established the key architectural features and was responsible for developing them and explaining them to both the client and the project team. GA's summary map is shown in figure 9.3 below.

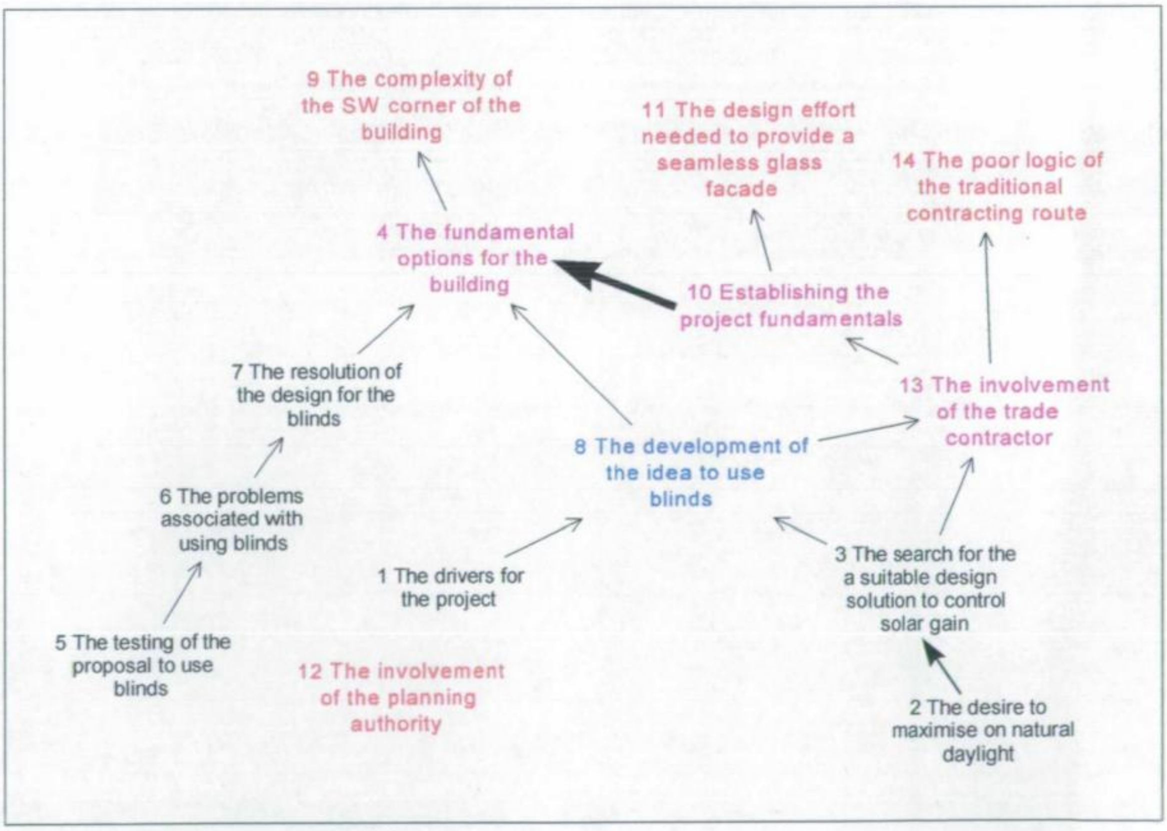


Figure 1 GA summary cognitive map

The summary map is straightforward with no loops found. The design process for the façade can be seen as a relatively coherent with the requirements for natural daylight producing the development of the blinds as a key element to the whole process. The outcomes for the process were the increasing complexity of the façade's design around the prominent SW corner, the effort needed to produce the particular style of seamless glass façade, envisaged by GA in the first instance and the problems which using the traditional contracting route causes to such complex design elements as the façade. The core concepts of the summary map (4, 8, 10, 13) are all related, with a particularly strong relationship between concepts 10 and 4 which relates to the early design work and in particular the way the designer tried to achieve the objectives set for the building using an individual interpretation of the implications for the design.

c. JP, Senior Project Engineer, Ove Arup & Partners

JP was involved in the Helicon project as the coordinating engineer responsible for ensuring that all OAP responsibilities for the services engineering were provided. As an electrical engineer JP was not directly responsible for the design for the façade, but as a senior manager on the project, JP was involved in the design meetings and monitored the design progress closely. JP's summary map is given in figure 9.4.

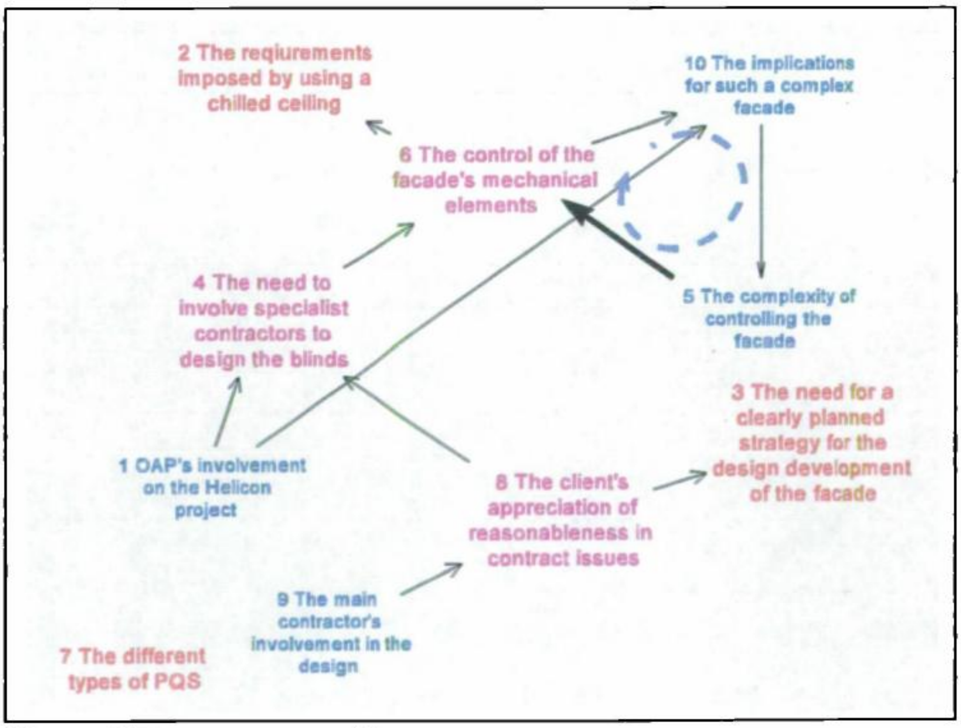


Figure 4 JP summary cognitive map

JP's summary map is more complex than that of the architect and this reflects the issues which resulted from the combination of business related objectives, such as an energy efficient building which also achieved the particular aesthetic requirements, which the architect was extremely keen to achieve. An important aspect of JP's summary map is the acknowledgement that the client's attitude was a significant factor in the design process. This positive approach enabled the specialist contractor to be used at the most appropriate time which allowed the complex design to develop in accordance with the imposed constraints. The loop present in figure 9.4 concerns the extremely complex operation of the façade and in particular the integrated operation of many mechanical aspects of the façade which have been necessary so as to provide the controlled interior climate as well as respond to a number of extreme conditions, from fire to very strong winds. The outcome of this sequence of events was a recognition of the complexity of using a chilled ceiling, which could be viewed as being under valued at the start of the design development for the façade. A separated element, cluster 7 of the map, is the discussion of the different types of PQS which OAP have encountered. The significance of this discussion was that the PQS on the Helicon took a significantly proactive approach to the design development which directly affected the atmosphere in which the design was developed.

d. CR, Senior Quantity Surveyor, Silk & Frazier

CR was one of the core team from Silk & Frazier who monitored the financial aspects of the Helicon project. The active involvement of the PQS during the design development had a significant impact on the process of the design development, although it is clear that the initially preferred design solution was continued with. CR's summary map is given in figure 9.5.

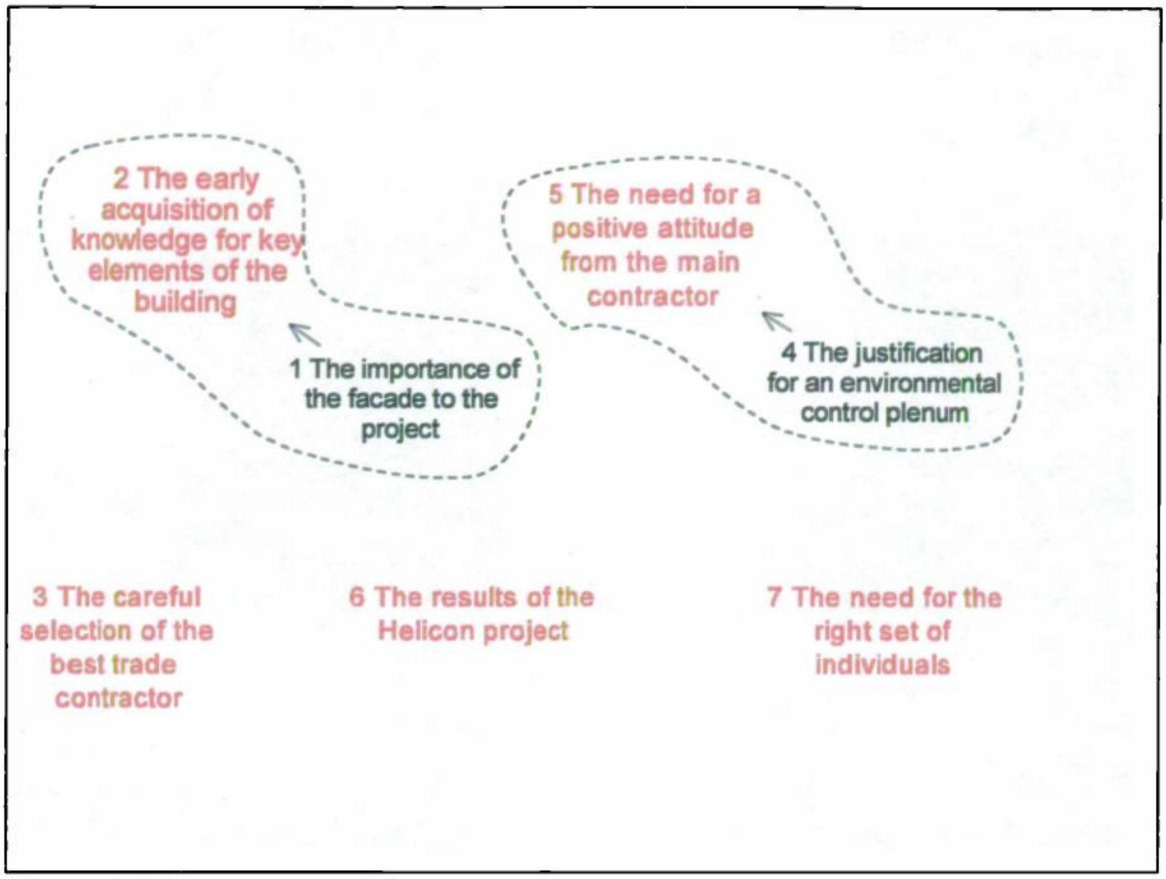


Figure 5 CR summary cognitive map

The summary map shown in figure 9.5 reveals a remarkably different style of map. The map reveals a number of disjointed elements which, although related to the Helicon project, do not appear to be part of a cohesive process. This style of map appears to suggest that the PQS identified a number of factors as being important and saw their duty to ensure that these differing factors were incorporated as part of the design process. The two separated groups within the summary map relate specifically to the Helicon's façade, with the recognition of early knowledge acquisition, cluster 2, and the need for a positive attitude from the main contractor, as a direct result of the need for a complex design solution in the form of the environmental control plenum. The individual elements shown in fig. 9.5, clusters 3, 6 & 7 cover both elements associated with the process, selecting the best trade contractor, as well as issues related to the setting up the project with the right individuals and finally the result of the project.

e. SB, Senior Project Manager, Scheldebauw

SB was directly involved in the design development of the façade as a lead designer with the Dutch company who were appointed to complete the design, manufacture and install the façade. SB's summary map is shown in 9.6.

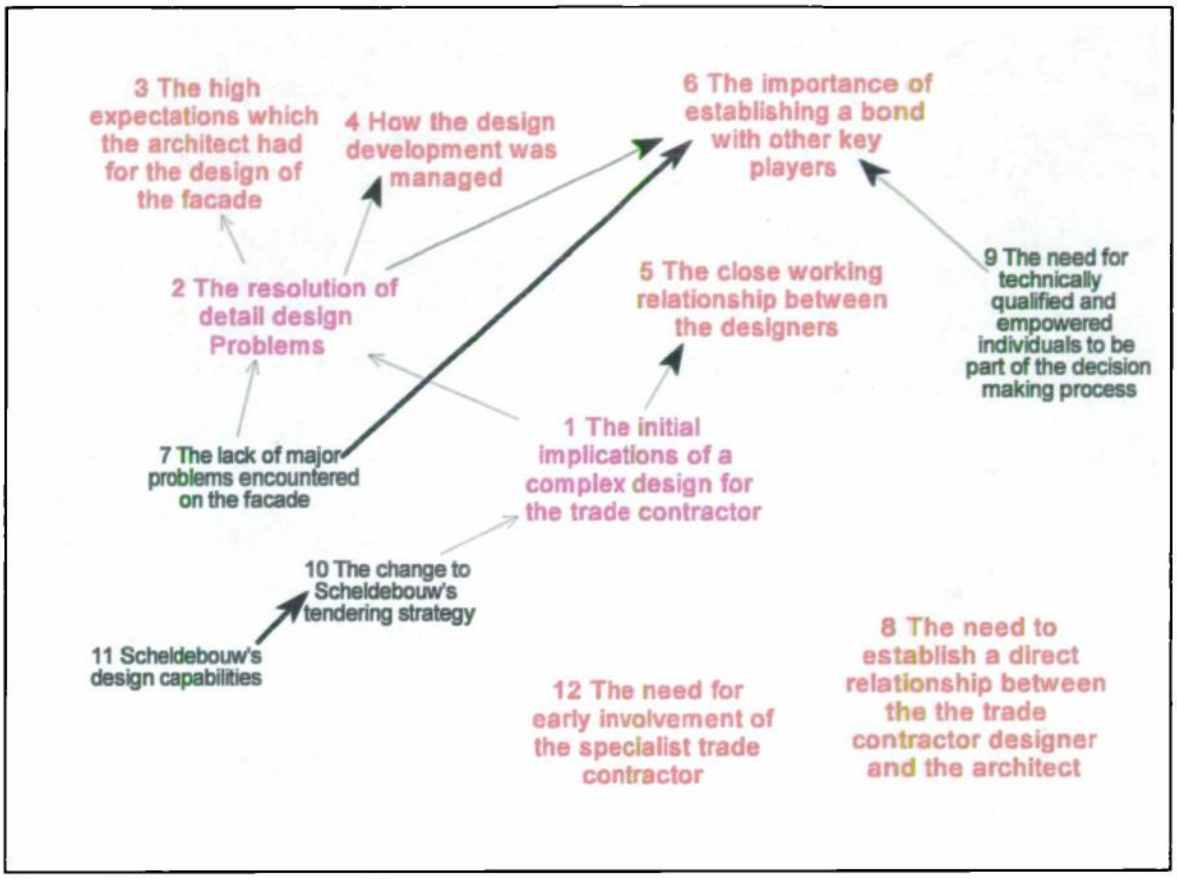


Figure 6 SB summary cognitive map

Figure 9.6 illustrates how there was a clear process involved in managing the design of the Helicon's façade. Commencing with issues related to the trade contractor's capabilities and strategy, the process centres on the initial implications for the trade contractor and then considers the outcomes. A clear theme of this summary map is the importance of early relationship establishment, trust and good, direct working relationships. Two recommendations made, clusters 8 and 12, clearly indicate the emphasis of 'good' and early relationships between the consultant design team and the designers from the specialist trade contractor.

9.5 Conclusions from the analysis of the Helicon project

The Helicon project provided a rare example of a speculative development on the edge of the City of London at a time in the business cycle when rental levels were depressed and there was a large volume of un-let office space available. The clear driver for the project was the securing of a blue chip tenant for the lower floors which, together with the presumed low cost of acquiring the site, meant that the developer had an opportunity to build a commercial building on top of the pre-let retail space which addressed all the current commercial, technical and environmental issues which were well recognised as disadvantages of the majority of the existing stock.

The selection of Sheppard Robson as the architect was a commercially motivated decision and the move of the project from one team within SR to the team including GA was an internal decision within SR. The commercially orientated brief, requiring an office building which could be let for a profit for a range of different user types, which would be cheaper to run and which provided a pleasant internal environment, allowed Sheppard Robson the potential to offer a large number of façade alternatives. The choice of a glass and steel façade, emphasising the transparency of the building, achieved a number of objectives as well as being personally liked by the Project Director, responsible for the project. The problem with this choice, one of solar gain and glare, was to be the biggest consultant design team problem, requiring a great deal of exploration, iteration and testing.

The design exercise was carefully monitored by the PQS who interpreted the design development into potential costs and offered these to the client for approval. This method of working was perceived differently by members of the consultant team who either saw it as a challenge to the design or a thorough service. This marked difference in view can be explained by considering that those who have the inspiration originally for the design will view the comments provided by those who are just considering the financial implications as threats and challenges. Alternatively, those who have to work with, and develop, the original design will prefer to have all the implications of the proposed solution considered at the time, thereby establishing a clear and solid footing from which to continue. The client was remarkably unaware of the underlying tensions being generated by this process, which indicates both the professionalism with which all parties conducted themselves in public and that the client was not expecting such tensions and therefore wasn't attuned to their presence. The tensions created between the PQS and the architect did not appear to affect the outcome, with the client endorsing the most expensive design solution to control the internal environment. The development of the blinds was crucial to the practical problems related to the sun and required the appointment of a specialist company to develop the design and manufacture blinds which specifically met both aesthetic and practical requirements. The direct appointment of Technical Blinds reflected the client's understanding of the issues which required the appointment of a competent organisation who could work quickly and effectively. The resultant design, which incorporated sophisticated control mechanisms, provided one of the most technically sophisticated façades available. The transformation of this design to a fully integrated and installed façade required a significant commitment from the trade contractor. The selection of an organisation which encompassed both the capability and capacity led to a world wide tender list. The use of a commercially based set of tender documents together with the recognition that there were criteria required which were difficult to place a financial value against, meant that there was a need to carefully consider the appointment. This process was a continuation of the way in which the main contractor was appointed. Here the contract form was altered during the post tender negotiations to reflect the nature of the submissions being made by the competing main contractor tenderers. The negotiated appointment of Laing London, following a competitive tender exercise, meant that they understood the culture of the project and agreed to a substantially 'tight' contract. Laing were part of the team who agreed the appointment of Scheldebauw who would be their sub contractor. The lump sum form of contract puts a great deal of emphasis on ensuring the design is complete, as failure to comply with the conditions of the contract leads to both delay and claims. Given this scenario it was unusual for the main contractor to permit such a detailed design development period between the architect and the trade contractor, however, given the nature of the façade's design complexity and the working relationship which existed between Sheppard Robson and the trade contractor, Laing London agreed that, as long they were kept informed of any developments, they had no objections to the establishment of a direct working relationship between these two parties. This could have caused many problems but Laing allowed direct discussions between the designers which enabled them to develop a substantially problem free design.

The creation of a team approach, having selected organisations who had worked together previously stands out as a significant asset for this project. The commitment of those working on the project was clear and even those who were sceptical of the proposed scheme, such as the Chief Planning Officer, were not excluded from the team. The benefit of such an attitude was a remarkably smooth development from initial brief, through the design, to the installation. Such a technically complex façade would be a challenge in any circumstances, but to achieve it in the conditions of a speculative development in the economic circumstances can be considered as a dramatic success. The success in delivering a functioning façade which enables the interior climate control equipment to operate whilst staying very close to the architect's original concept and achieving the client's commercially driven criteria is a significant achievement.

Figure 9.7 on the following page are photographs of the completed façade.


M&S

Chapter Ten
Comparative Results

10.1 Introduction
The use of cognitive mapping has provided a new way of presenting complex qualitative case study data in construction management. The construction and subsequent analysis of these maps provides the opportunity to review the data, often in ways which are not immediately apparent. The results of the analysis are therefore justifiable and, with the accepted restrictions associated with data derived from personal perceptions, are rigorous. The ability to draw clear conclusions from individual interviews in such a concise way is one of the main advantages of this methodology.

The benefit of using such a methodology is that complex results can be derived from the analysed data. These results, which interpret the analysis using cognitive mapping, are based on more than just the researcher's primary understanding of the case study evidence, which would normally be associated with such a qualitative area of research. As such, validation for these results can be verified easily by reference back to the cognitive maps. As this 'trail' of justification is possible right back to the original interview, the rigour of the results is of significant importance.

Following the detailed issues which have been presented through the individual summary cognitive maps in each of the individual case study chapters (ch. 7, 8 & 9), the next stage, which the methodology allows, is the combination of these individual maps into an overall map representing the process of the design management of the façade for each project. The potential benefit of such a map is that it represents, in a summarised form, all the issues and their interrelationships which were important to the project. In terms of the project, it is the final stage in condensing and analysing the process as viewed by those key players who were active in managing or decision making. Figure 10.1 represents the various levels of analysis and result outputs for each project with the summit of the pyramid being the culmination of the research into each case. The data contained in this stage is therefore directly related to the previous stages.

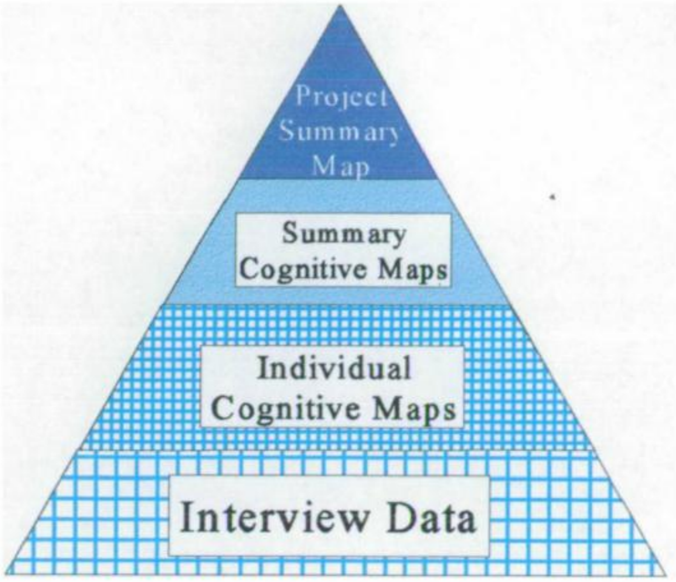


Figure 10.1 The Summarising of the Data

To commence this stage of the analysis, each case study will be considered individually in order to draw out the features for the project.

10.2 The Harlow SC1 project case summary map

Considering the actual results presented in chapter seven, there are a multitude of issues which relate to this very interesting case study. The individual issues of the case have been considered separately, but the use of cognitive mapping allows one final level of analysis to take place which draws all the individual threads together. Using the same types of analysis for the individual cognitive maps, together with the ability to merge concepts from different maps, it is possible to create a complete map of the Harlow SC1 case. This final stage of analysis requires the reviewing of all the individual overall cognitive maps to identify concepts which are making the same point or which provide either an explanation, or are a consequence, of a concept from a different map. This requires the researcher to have a clear understanding of the issues involved. As this stage is attempting to create something which is not based directly on any one person's data, the concepts which are merged or linked are the limited to the most obvious and, where there is any doubt, are left. Figure 10.2 has three such concepts, 205, 804 and 807. Having created a case study based cognitive map, the same forms of analysis are performed to reduce complexity. The resultant simplified map is shown in figure 10.2.

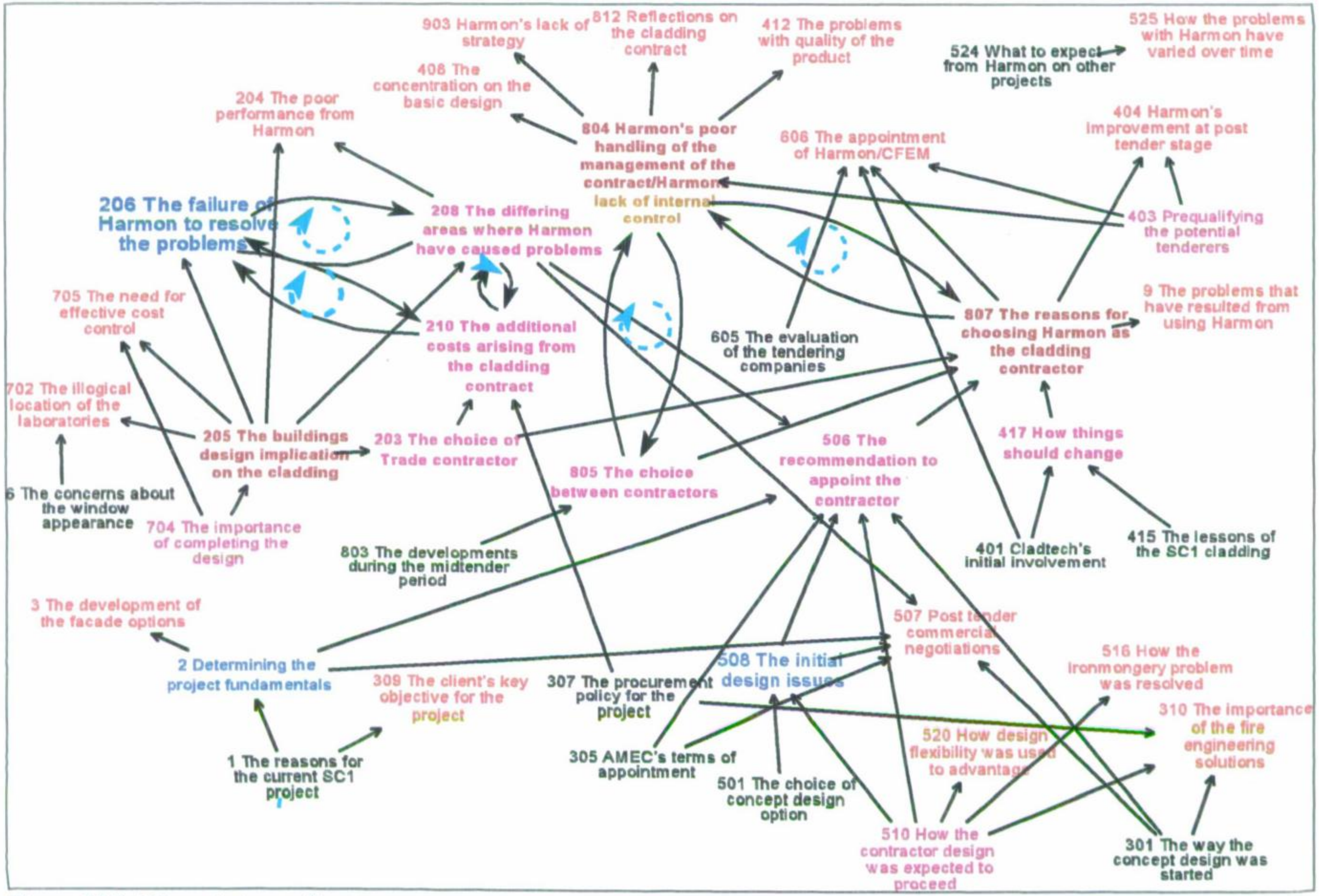


Figure 10.2 SC1 project overall summary map

Figure 10.2 represents the core issues involved on the design management of the SC1 case study. This map represents a significant advance in the ability to be able to represent a highly complicated area of project management in a way that is both relatively straightforward and stimulating. The particular importance of figure 10.2 is that it attempts to represent the process of design management. This process, as it currently exists, combines all the traditionally recognised elements of project management in a way which can be considered by practitioners, management consultants, and academia. Such a 'simple' summary map of the process is a fundamental requirement for Business Process Reengineering, and this map provides a route for exploring, in as much detail as necessary, the current procedures and systems, and allows for a more simple process to be created.

Careful analysis of figure 10.2 reveals a complex series of cause and effects from which can be drawn some interesting factors. The first area of interest is the appearance of a major loop. This is shown in figure 10.3.

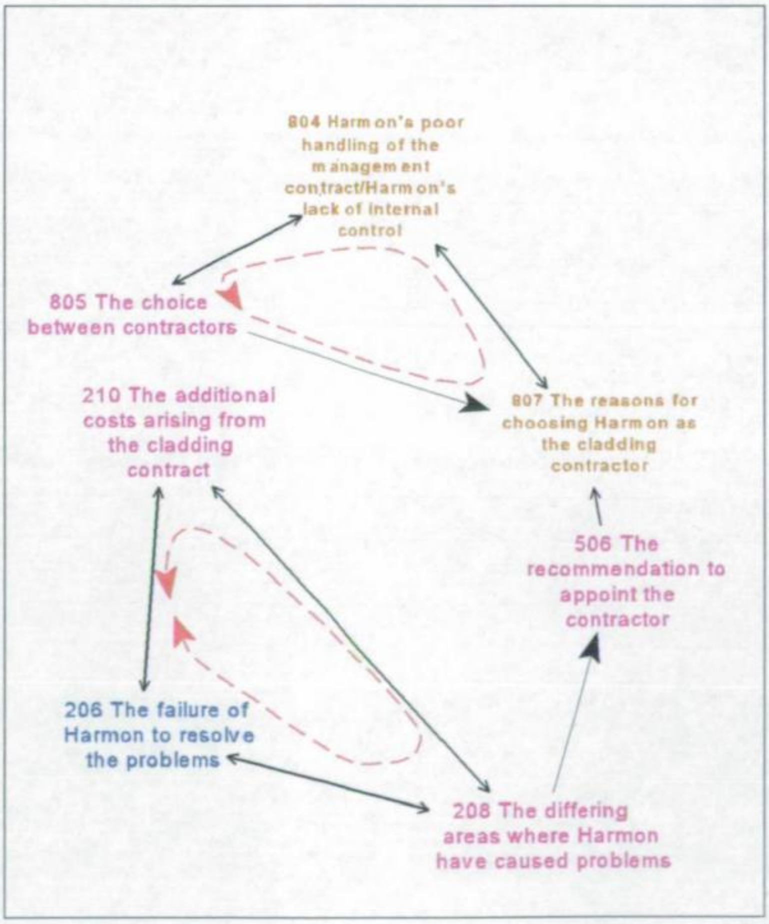


Figure 10.3 SC1 project summary map main loop

Figure 10.3 clearly indicates how the choice of contractor and the subsequent appointment of HarmonCFEM were related to poor management and increased costs. The link between the two sub-loops shown in figure 10.3 have a common theme, which is the lack of control by the trade contractor. The link itself, being the recommendation to appoint, can be seen as a key element of the loop which is intuitively sensible and which can be seen to be an area where the pre-planned policies, which were established by all parties, were significantly altered at a very late stage by the client. This change was to gain the benefit from the supposed economies available by introducing an additional and substantial amount of work. As recorded previously, there were misgivings voiced about this policy and an awareness that the quantity of work, both in design and manufacturing terms, was likely to be too big for any single contractor. With such concerns, it is clear that the tendering companies needed to be able to demonstrate a clear ability to handle such a large contract. It is clear from the wide range of problems which occurred that the management of such a large quantity of work, under the control of two independent construction management companies, was not carried out sufficiently.

Following the theme of the loop shown in figure 10.3, the summary map (10.2) can be considered by examining it for concepts which follow a theme. Figure 10.4, on the following page, is an adapted version of 10.2 which highlights the concepts that relate to the trade contractor's performance. Both the number of concepts (11 from 43, 26%) and the consistency of the themes suggest that the appointment of the wrong trade contractor overwhelmed the predicted management system which had been set up by the core project players. The result of this was a continual 'battle' to manage the façade's design, production and installation.

The remainder of the summary map follows a logical form of argument starting with issues relating to the way the project was intended to progress and the important aspects of the project and their implications. At the 'top' of the map are the consequences and outcomes of the various previous actions and events, which is what would be expected in cognitive mapping terms.

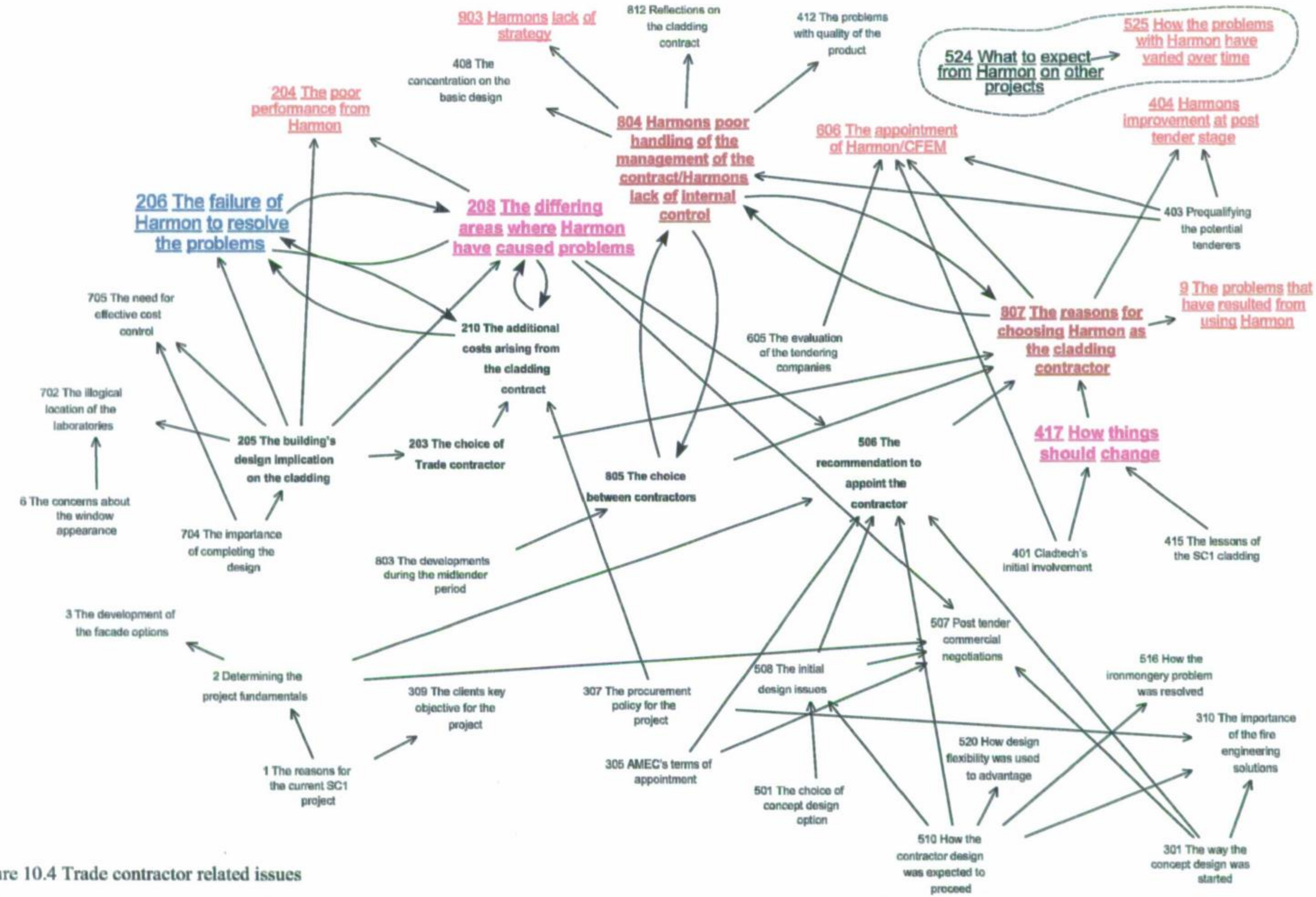


Figure 10.4 Trade contractor related issues

10.3 The Boots D10 project Summary Map

The Boots D10 project summary map has been constructed following the same procedures as were used for the Harlow SC1 project, but as the project was smaller and used an integrated design/manager there were fewer individual maps to integrate. Figure 10.5 on the following page is the summary map from the Boots D10 project. Figure 10.5 contains a number of interesting issues and themes. Firstly, there are five loops detected, the two largest of which are shown in figure 10.6.

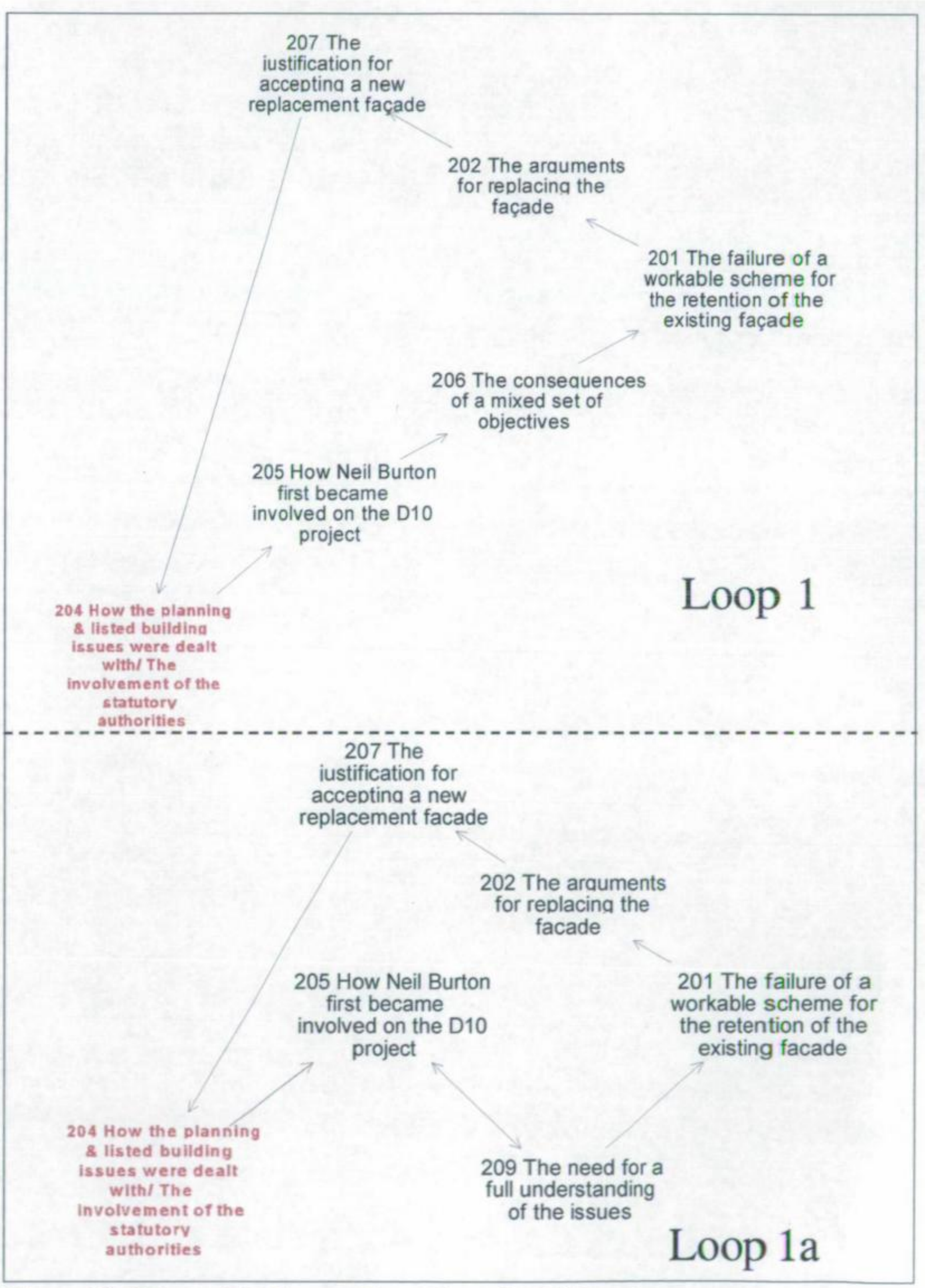


Figure 10.6 Figure 10.6 Largest loops from the D10 project

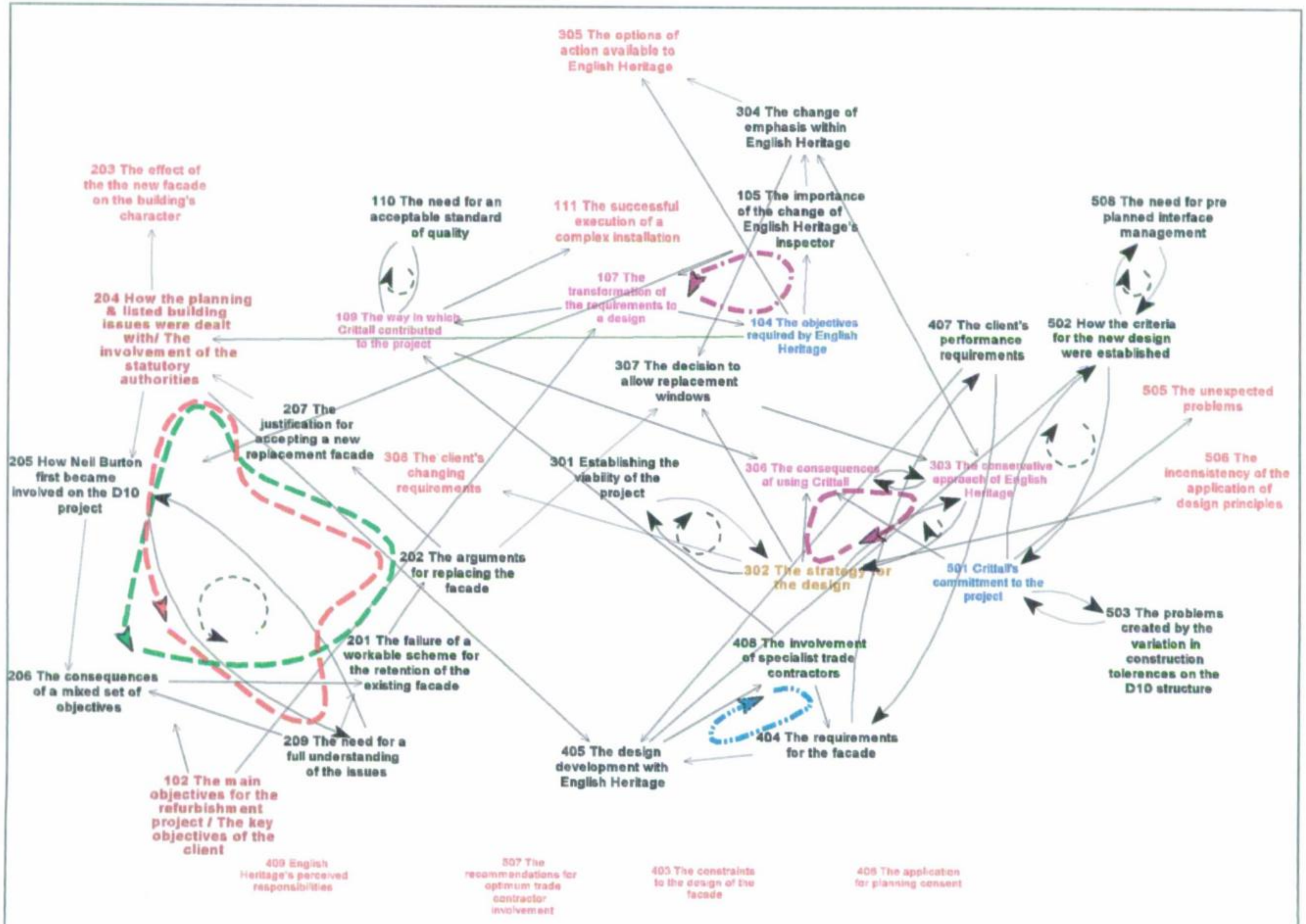


Figure 10.5 D10 project overall summary map

The loops (1 and 1a) shown in figure 10.6 are associated with the complex issue of the decision to replace the façade. As recorded in the case description, this issue was extraordinarily important and protracted. Even with the involvement of a new English Heritage Inspector the decision to replace the original façade was so fundamental to both the project and those at English Heritage that the iterations necessary, before the final scheme was accepted, were extensive.

The second loop shown in figure 10.7 focuses on the influence of the English Heritage Inspector. Figure 10.7 indicates that the objectives of English Heritage were dependent upon the individual Inspector, which accords with the empowered status of each Inspector. By changing the Inspector there is therefore an associated change to the objectives, which feeds through to the design.

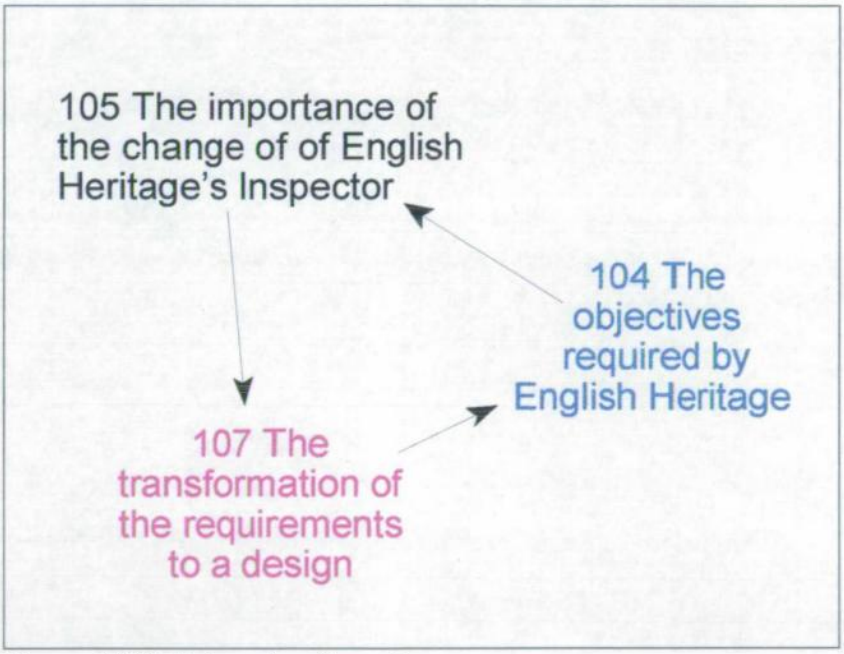


Figure 10.8 D10 project loop 2

The next loop, shown in figure 10.8 on the following page, concerns the actual process of developing a workable design. Figure 10.8 shows how the design, based on much discussion between the parties, required the involvement of a specialist contractor.

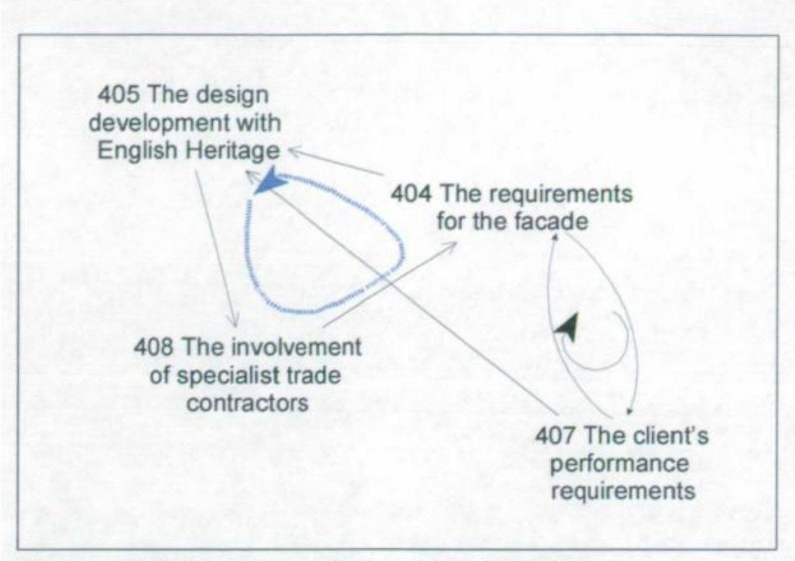


Figure 10.9 The inter-relationship of needs

The involvement of a specialist contractor will clearly bring a new perspective which itself feeds into the design development. Associated with this loop is concept 501 which concerns the commitment of the trade contractor. This concept has two loops, each dealing with one issue. This relationship is shown in 10.9

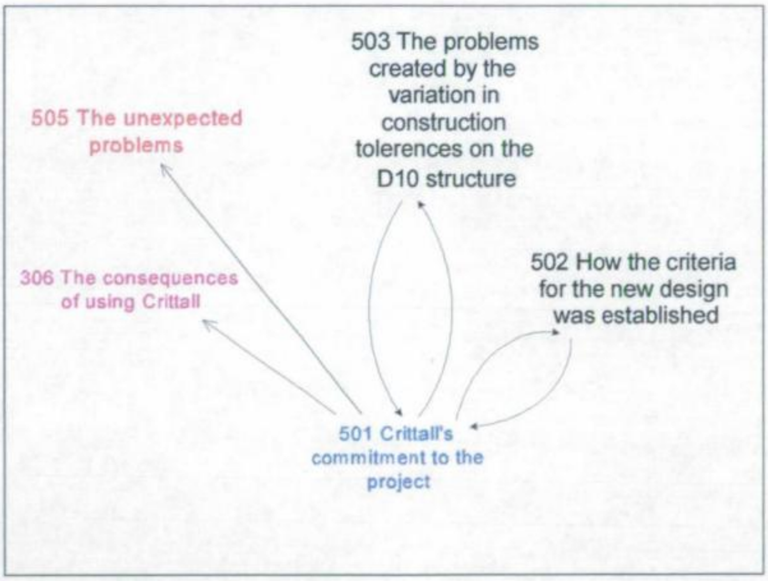


Figure 10.10 The commitment of the trade contractor

Figure 10.9 relates the concept dealing with the trade contractor's commitment (501) to the issues of establishing the design criteria which, in turn, reinforced the commitment to the project. A similar type of argument was found for the practical issues associated with the wide range in tolerances found in the existing structure.

The final loop, which combines elements of the previously described loops, is shown in figure 10.10.

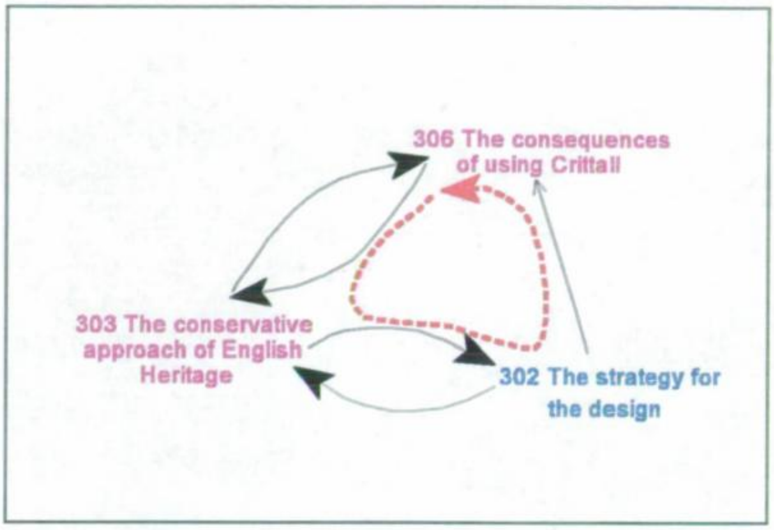


Figure 10.11 D10 project loop 4

The fourth loop includes the outcomes of the involvement of the parties. Each concept represents a cluster in its own right, but at the summary level the importance is on how each influences the other. Interestingly, the consequences of using Crittall influenced the conservative approach by English Heritage. This is explained by Crittall's sense of heritage, as they had originally installed the first façade and were keen to be associated with the refurbishment; therefore they worked to accommodate English Heritage's conservative requirements wherever possible. This then influenced the strategy for the management of the design.

Having examined all the individual features of note, an overall evaluation of the summary map can be attempted. The Boots summary map is clearly complex, with many areas being subject to complex relationships, not always in a straightforward cause and effect way. However, it is possible to draw out some key themes which are important.

The first area is the clearly stated requirements which the client specified. These criteria led the design to follow a clear path which required the replacement of the existing fenestration. This leads to the second and probably the most single important aspect: the way in which

English Heritage were required to be involved. As the building was of significant national importance it would be expected that it would receive an extremely critical evaluation from English Heritage; however, the dramatic change that took place when the English Heritage Inspector changed, indicates that the project's potential success or failure lay in the hands of the correct mix of individuals. With the change of just one key player the progress on the design of the façade went from stagnation and frustration to rapid progress. The lack of further problems can be considered as a result of the extreme thoroughness with which the design was treated, with the exception of a few specific areas which appeared to not receive the same level of attention. The only explanation offered for this is that, by negotiation, less obvious areas were allowed to progress in a more straightforward design because of time and cost pressures.

The final area is the use of an experienced, committed and well resourced trade contractor as part of the project's design team. The use of Crittall was crucial to the success of the project. Not only did they hold a substantial amount of expert knowledge on the building's history, but they clearly recognised the opportunity to gain a positive image for their company by carrying out a good job. The ability to produce a product that met the wide range of performance, aesthetic and cost criteria was complex. To then be able to install the new design into a building which suffered from extreme variations in tolerance compounded this complexity.

It is unlikely that the project would have progressed on a day-to-day basis without much tension and probable acrimony, yet the project was a success and all parties reflected positively on the involvement of the other players. It is worth recording that there existed a strong view that English Heritage could not continue to function under such a system that allows individual Inspectors the power which they currently employ. With an ever increasing number of primarily functional buildings, which are either still in operation or are now redundant, being listed, English Heritage will face situations where they are challenged by experts who do not necessarily agree with their narrow view of what is desirable.

The Boots D10 refurbishment ended up with a team effort involving all the players and its completion, within budget and to the satisfaction of the client. The awards which it has won and the associated positive comments, suggest that nationally important buildings can be maintained on a commercial basis while achieving the core heritage objectives.

10.4 The Helicon Summary Map

In contrast to the Boots D10 project, the summary map for the Helicon project, given in figure 10.11 on the following page, has only one loop present which is shown in figure 10.12.

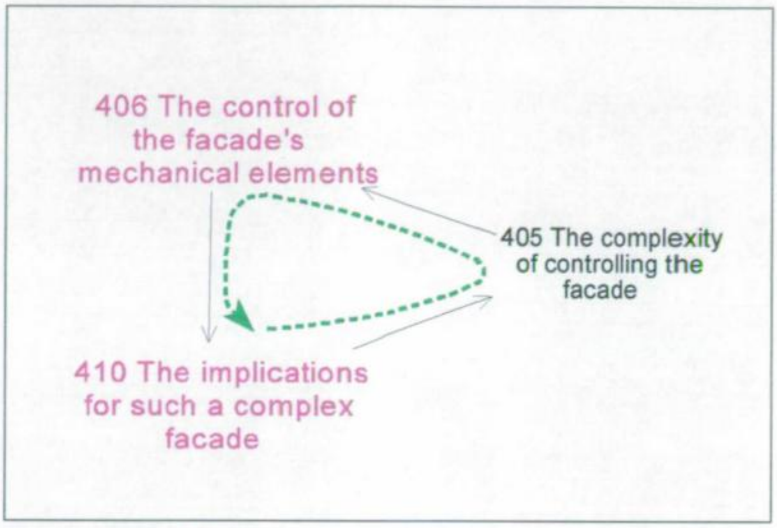


Figure 10.13 Helicon loop 1

This loop addresses the particular problems created by the need to use the blinds, located within the façade, to respond to a number of environmental factors as well as operating in a controlled and acceptable way. The result was for a highly iterative process of development which, although tested in extensive simulation, is still subject to reasonable uncertainty when in operation.

With the exception of the one loop, the remainder of the Helicon summary map represents a relatively simple evolution of issues which explain the development of the façade. Starting at the bottom of the map, the issues here relate in general to the selection of the right individuals who work within a framework of reasonableness. From this starting point, the 'tails', the development of the façade takes place which, in the Helicon's case, pushed the boundaries of façade design to new levels of complexity and innovation. The particular requirements of the overall design for the building, together with commercial considerations,

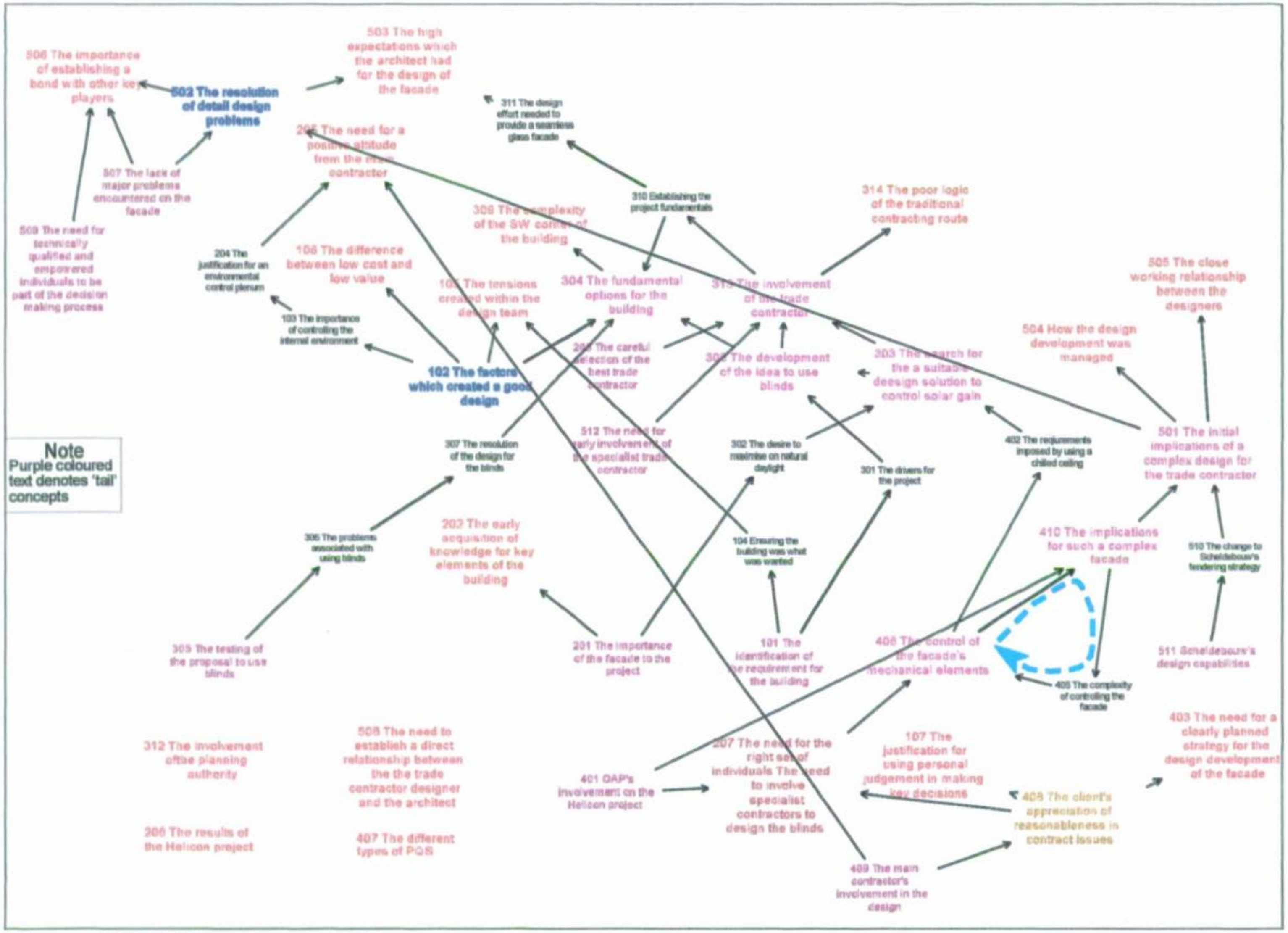


Figure 10.11 Helicon Summary Map

led to the development of an innovative type of blind. The use of a specialist manufacturer, on a negotiated fee basis, enabled the best skilled design personnel to work within a short timescale to develop, test and manufacture a suitable blind product. This period of design development was extremely hectic, with many parallel tasks being undertaken. The importance of the right mix of individuals working in a 'reasonable' way can be seen to be a very important factor during this stage. Even with these individuals, the amount of work necessary and the constraints worked under were substantial, requiring significant personal effort and commitment. For reasons which can be considered under headings such as personal challenge, job satisfaction and professional pride, the design was developed which achieved practical, financial and timescale constraints. The culmination of this intensive period of development was the mock-up and testing of the façade which, by its very nature, could produce many problems. This stage went almost faultlessly with only a few minor issues arising, which in the context of the project's design complexity, can be considered as a remarkable achievement.

The final area of the summary map are those issues at the top of the map. These are related to considerations of the way the design progressed. There are both the positive aspects, such as the need for establishing a bond, and the negative which were the strains and tensions created within the professional team through the detailed involvement of the PQS during the design stage's development and the fundamental problems created by constraints imposed by the procurement procedures. The results demonstrate that where there is a clear strategy operated fairly and using the right individuals, substantial success can be achieved which brings dramatic architecture, advanced technology and many user advantages on a project operated within a fundamentally commercial cautious environment.

10.5 Drawing out the Overall Results

Having considered the data from each of the case studies, first in detail and then at a summary level, it is now possible to consider the results of applying cognitive mapping to the generic construction project. In diagrammatic terms the research is now at the summit of the data pyramid as shown in figure 10.13.

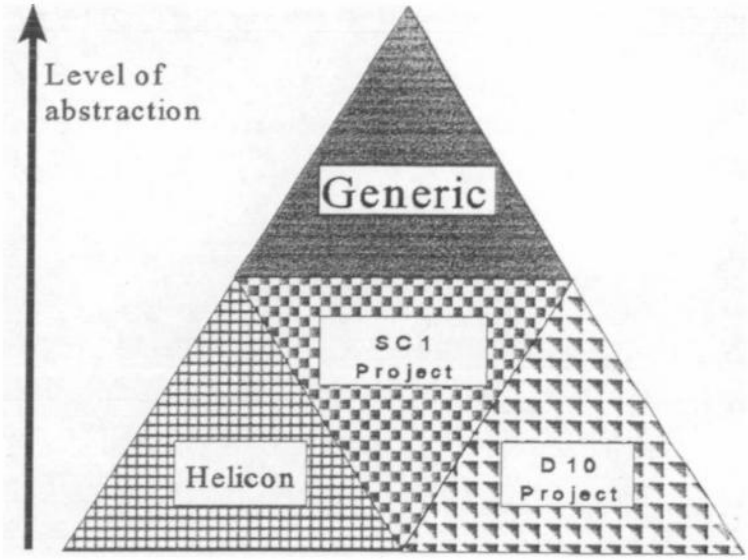


Figure 10.14 Increasing level of summary for the data

The results of the research across three distinctly different types of construction project are of significant interest. The first key finding is that the methodology of cognitive mapping is applicable over the different data sets and is capable of handling and providing useful results. The results obtained have been capable of increasing levels of summary with the safeguard of not losing data integrity. Clearly, as the data are summarised, so there is significant responsibility on behalf of those interpreting the data, as to what the results mean. This is where the established nature of cognitive mapping is significant. The ability to explore the results, which have been drawn from individual perceptions, but analysed using objective criteria written into the software, enable complex inter-related issues to be considered in a holistic fashion. Within each project this is useful as the strategic decision makers can see how the various parties involved are both influenced by and influence the strategy. Significantly the results of the cognitive mapping enable fundamental decisions to be taken in the knowledge that there is a traceable route from cause to effect. At a *supra* project level the researcher is capable of drawing general conclusions. Although this may be available to researchers using a more traditional narrative form of analysis, it is argued that the depth and objectivity to which the data has been subjected enables the generalisations to be made with more confidence.

Secondly, the use of the cognitive mapping methodology has achieved the desired aim of being able to consider the complex inter-related data in a rigorous way which has facilitated a clearer understanding of the issues related to the management of the design process as it exists in the construction industry. The ability to produce comparable summary maps from a wide range of project types clearly enables a greater understanding of the general issues.

If the summary maps are considered as the only data set then they, of themselves, contain a valuable source of data which helps third parties understand the issues involved in the management of the design, as well as assisting those involved in the management of these projects to make decisions. Thus, simply by looking at the concepts which are at the head of the maps for the individual case studies (see figures 10.2, 10.6 and 10.11), one can see that key points were concerns about the strategy for the trade contractor (fig. 10.2), the options which English Heritage needed to consider (concept 305) and the importance of expectations of the architect and need for close working relationships (fig. 10.11). These straightforward issues can be seen as the results of each of the cases, with the Boots and Helicon cases reflecting on how the projects were a success, while the Harlow SC1 project considers mainly issues related to the disappointing experience associated with the trade contractor. Within each of the summary maps there are interesting issues which, if sufficiently interesting, can be traced back to the original data, thereby informing the reader on the specific detail that led to the overall summary.

10.6 The Affect on Construction Management

The importance of a strategy for the whole project has been shown to be located within the territory of the client. This strategy will often be complex, with many diverse elements, and it is clear from all three projects that the general understanding of this strategy by the other main project players is critical. Where such a strategy does not appear to exist there is always a risk that radical change can be introduced with no criteria to evaluate it against. Part of the strategy is the clear identification of criteria on which to judge suitable prospective individuals and companies. On both the Helicon and Boots projects there were clear reasons why the client chose the particular players. These were either because of prior associations, as in the case of Boots with AMEC and the use of Crittall who carried out the original installation, or on the Helicon, where Scheldebauw had worked previously with Sheppard Robson and London and Manchester had a long relationship with Silk and Fraser. These prior relationships removed a great deal of potential problems, even though most of the relationships were tested commercially to ensure that an unreasonably high price was not being charged (Boots - AMEC, Sheppard Robson - Scheldebauw). Although the procedures for the appointment of these players were part of the original cognitive maps, they were not significant and do not feature as part of the summary level maps for the Helicon and Boots. On the Harlow SC1 project, however, there was a strategy dominated ultimately by cheapest price. Without any other particular criteria, a thorough *a priori* evaluation was carried out but this selection procedure was subject to interference from both external parties to the project and to 'rule breaking'. The quantity and diversity of the problems caused by the appointment of the 'wrong' trade contractor put into jeopardy the extensive amount of work which had been carried out previously. The problems created were not expected and had not had resources or time set aside to resolve them. This led to problems both directly related to the façade's design as well as more generally throughout the project as personnel were diverted to solve the problems. The result was additional costs which directly countered the original objective.

10.7 The Discovery of Loops

The existence of loops was not expected at the summary level, as loops within the data set itself are checked for during the building of the original cognitive maps and were not normally present as most lines of argument were linear. Therefore, when the summary maps were created using the clusters, as previously explained in chapter six, it was expected that the clusters would relate to each other in a similar fashion. When the summary maps were plotted and it was found that loops were present, it suggested a number of possibilities. Firstly, there was a fault in the software or the application of the methodology. Secondly, the loops were valid but insignificant, a byproduct of the analysis. Lastly, the loops were both valid and significant and provided an insight into the complexity of the issues in some way. To test which of these explanations were true, experts at the University of Strathclyde's Department of Management Science were contacted to ensure that the presence of loops was not erroneous. This hypothesis was rejected as the application of the methodology had been correct. The second and third alternatives were therefore left as being the only explanations. To be able to consider the matter further, an investigation was carried out to explore the causes of the loops. This preliminary investigation is considered next.

10.8 The Theoretical Underpinning of the Methodological Approach

As one of the requirements for this research was to take the information from the cognitive maps and distil it to a summary level, the question of the intellectual validity of the methodology became important. Specifically, the objective of representing a complex process, such as that of the design of a complex element of a construction project, had to have a theoretical basis on which the results could be built. Such a theory is found in the area of systems thinking and specifically in the area of systems modelling. Although able to be traced back to the eighteenth century, systems thinking has become increasingly important in the last thirty years as the modern world becomes far more complex. It can often be found that individuals are overwhelmed by the complexity of the situation facing them, admitting that they cannot understand what is going on or 'blaming the system!'. Systems thinking according to Senge (1990) is:

> '..a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static "snapshots".' (P.68)

To understand how systems operate it is necessary to identify two issues. Firstly, the constituent elements of the systems must be captured and secondly, the linkages describing the *influence* of one element over another must be understood. For simple systems there may only be two or three component elements with a corresponding number of linkages between. As systems become more complex so the number of elements goes up as well as the linkages between them. Some of mankind's most complex problems, associated with environmental change and resource depletion, are examples where science is striving to understand the system which is at work. Weather prediction is a good example of a complex system which has many components which act and react together. Meteorology is using ever more sophisticated sampling and recording devices to understand the components which comprise the system and is forced to use some of the most powerful computers available to run simulations to try and mimic nature. An offshoot of the area of systems thinking has been the development of chaos theory which tries to understand how small changes in complex systems can have dramatic effects. This area of research has been applied to both the natural world, investigating turbulence and hurricane formation, as well as in economics and business where it has tried to explain stock market crashes or rapid currency inflation.

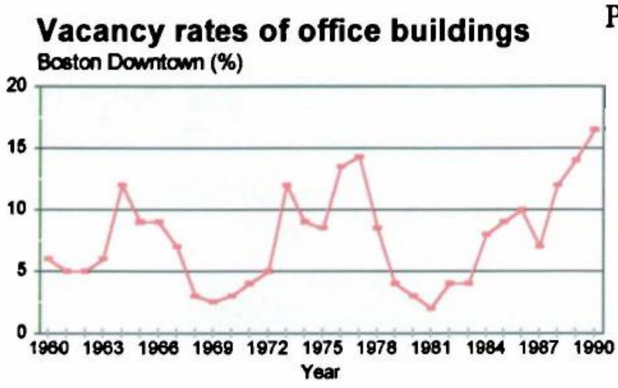
Systems can be either stable or unstable with some systems adopting a Newtonian equilibrium with inherent stability. An example of such a system would be the human response to thirst where water is drunk until a point of satiation is reached. In such a stable system, disruption only occurs when external factors intervene. Examples of such are drought or the introduction of drugs such as Ecstasy which interfere with the human body's internal temperature control mechanisms. Other systems are inherently unstable and need continual intervention to stop them from disintegrating. An example of such a system is the generation of electricity from nuclear fissionable fuel. The disaster at Chenobyl dramatically illustrates the consequences of a failure to intervene.

In the business world it is necessary to understand how markets operate, firms function and economies develop. All these areas, and many more, are capable of being viewed from a systems perspective. This is an established speciality within many business schools. The objective of this form of analysis is to understand how interdependent elements relate and influence both themselves and the larger system, of which they are a part. Such understanding enables researchers, analysts and consultants to model the system, simulate it and ultimately predict it or alter it for enhanced performance. By considering complex real world situations from a systems viewpoint, clarity is brought to bear on otherwise opaque problems. The aim of the systems based researcher is therefore to completely understand the system under investigation and so be able to anticipate or alter the outcome.

System modelling uses graphical representation to illustrate the model as it is understood. This graphical representation draws upon all the factors which influence the system. There is a combination of actions, events, and behaviour, all of which contribute to the complex operation of the complete system. One of the key elements of system modelling is the identification of feedback structures. These are represented by causal loops which can be either balancing or reinforcing.

To illustrate the value of a system approach, and how it is represented, the following example is taken from the Financial Times and concerns the vacancy rate for office space.

Panel A



Panel B

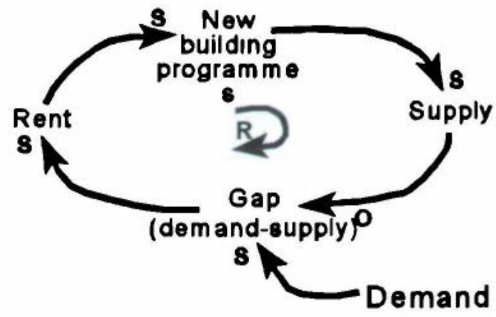


Figure 10.14 office space in Boston Source: Financial Times 8 12/95

Panel A of figure 10.14 above records the cyclical nature of vacant office space in Boston, whilst panel B is the system loop which describes the behaviours and events which lead to the cycle. Starting with the external factor to the loop, which is the demand for office space; when the demand for the space is greater than the supply, a gap appears in the demand supply relationship. To show how one factor influences another, the letters S and O are used to represent supportive (S) or opposing (O) arguments. The Demand-Supply Gap relationship is therefore a supportive argument. Once a gap appears for office space, the rental value for existing office space will increase, which in turn provides the incentive for developers to enter the market to provide new space, hence increasing supply. This increased supply of office space reduces the Demand-Supply Gap, this being an example of an opposing argument. The system is then in equilibrium, and will remain so until there is an outside influence, such as additional demand. The system used in this example can be seen to be a reinforcing system with new office space being created as a result of external factors; the opposite form of system would be a balancing system which occurs when parts of the system operate to counter the drivers of the system.

The ability to model systems using such a graphical representation enables both external agents and those who are employed within the system to understand how that system functions. When the level of complexity of the system increases, so the modelling technique enables the various sub-systems to be identified, and analysis focused on them. Thus for example figure 10.15 shows the modelling of a restaurant chain.

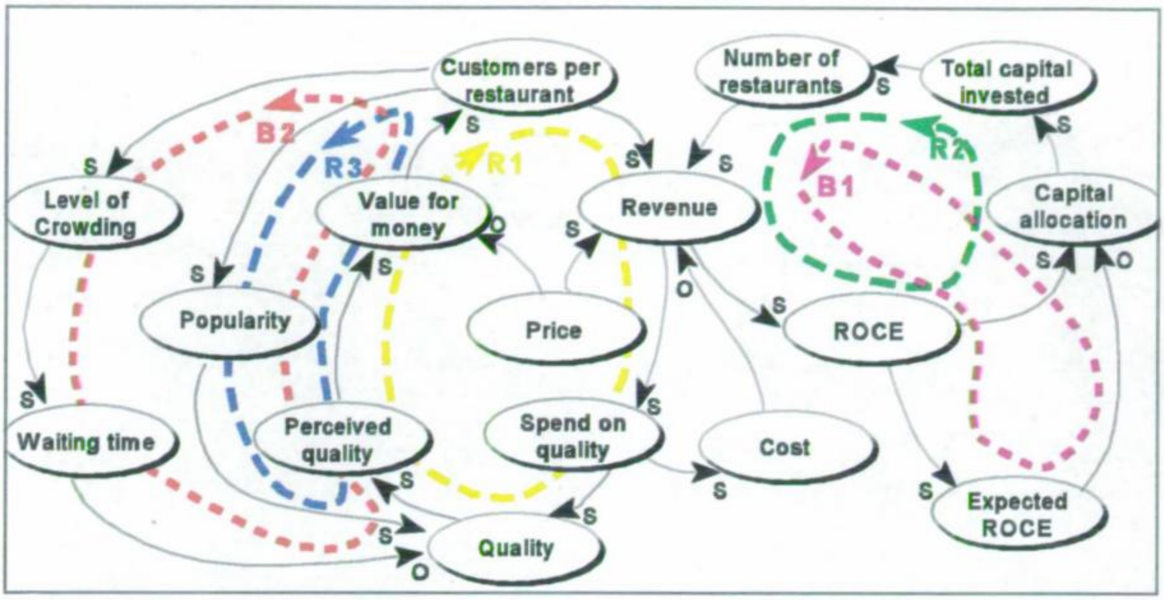


Figure 10.15 System model for a restaurant chain Source: adapted from Financial Times 8 12 95

Figure 10.15 represents the simplified system which explains the operation of a restaurant chain which is part of a larger conglomerate. The model consists of five main loops, three reinforcing ones (R1-R3) and two balancing ones (B1 & B2). The loop R1 depicts the scenario where initial success leads to greater subsequent success. More revenue allows for increased expenditure on quality, which is recognised by the clientele, which increases the number of customers, so raising the revenue. The loops R2 and B1 relate to the allocation of capital. As part of a larger conglomerate, it would be expected that there would be internal competition for resources, with the head office making the decision as to which part of the company receives what proportion. In this case the decision is based on the previous performance of each division together with the expectations about the future. The final loops (B2 &R3) deal with issues of the restaurant's popularity and overcrowding If a restaurant were empty, this would normally be seen as indicative of its poor quality. As a restaurant becomes more popular, so potential customers perceive the restaurant as having a higher quality, which leads to the restaurant becoming more popular. If this trend continued, the eventual result for customers could be a wait of several hours for a seat, or weeks for a reservation. In this case many customers may decide that it is not worth the wait, as the quality of the overall experience is reduced. This leads to the balancing loop B2.

The model represented in figure 10.15 is extremely useful for understanding the interrelationships involved, and can convey a large amount of information. There is, however, a limit to the complexity of the diagrammatic form, beyond which the interpretation of the graphical representation is so complex that the reader is unable to interpret the results. In system modelling the understanding of the system can be gained from building such models, but the real value comes when simulation models are constructed within a computer and are programmed to respond to changing variables in each of the model elements. The basis of this computer simulation is, however, based on an understanding of the basic system which can be represented by using diagrams similar to those in figures 10.14 and 10.15.

The attempt at mapping the process which occurred during the design of the façade on three separate projects has resulted in the production of such system models. The elements of the system could be influencing factors, resultant effects or contributory issues. As the results of the research show, all three case studies were capable of being reduced to a single map which summarised the process for that project, identifying the main issues and their relationship with each other. Although not as refined as the models given in figure 10.14 and 10.15, the results presented earlier in this chapter do convey the same style of information. This suggests that there is considerable value in attempting such endeavours in future, as with more cases studied, the greater will be the possibility of summarising to a *supra* project level resulting in a definitive process for design management, particularly at a project element level. The value of this contribution is not only that it is novel but, more importantly, it offers those who are actually engaged in the onerous task of managing the complex area of construction design, the opportunity to view the process which they are involved in. By examination, interrogation and discussion it is possible that improvements could be made to future projects which could improve performance. This philosophy is at the heart of the Business Excellence Model advocated initially through the US Baldridge Award and more recently introduced into Europe and the UK through the British Quality Foundation. Such attention to performance improvement by examination of the process is seen as being at the core of quality improvement as well as at the centre of the Business Process Reengineering work. It is timely that this research should coincide with the Design Council's funded research carried out by Oakland Consulting PLC into how the design process can fit into the business excellence model.

Expanding on the potential for understanding the complexity and recommending change, the final chapter will draw conclusions on the issues related to the management of the design process on complex construction projects and makes suggestions for ways in which those participating in the construction industry can improve the effectiveness of their endeavours leading to both greater satisfaction from those involved as well as better performance as identified by the usual project performance metrics.

Chapter Eleven
Conclusions

11.1 Introduction

The importance of the design process to the construction of a new building or facility is undisputed. The management of this process has been increasingly recognised as an important part of construction project management. This research has attempted to explore what this process is by using the information contained on real projects by those who were actively engaged in their management.

The key words for the research are **project, complexity, uncertainty, design, information, management** and **process**. Certain combinations of these words are well recognised and yet there is a lack of established understanding as to how information is managed as a process on projects which are often uncertain and complex.

The work of Galbraith (1977) started with a basic premise that organisations deal with uncertainty. According to Galbraith

> 'uncertainty is the difference between the amount of information required to perform the task and the amount of information already possessed by the organisation'. (P.36)

Information is the key to reducing uncertainty and Galbraith examined the various tools, techniques, and frameworks which organisations used. As such organisations could be viewed as information processing systems it is from this conceptual viewpoint that we can consider construction projects. These temporary quasi-organisations established for the duration of the construction or refurbishment of a building or facility can be considered in the way developed by Galbraith. Here the task is to reduce uncertainty through the creation, manipulation and communication of information both inter and intra the project players. It is the way that the personnel working on a particular project, forming what are generally referred to as project teams, but more accurately described as being project coalitions, acquire and subsequently manage this information that has been at the root of this research.

Galbraith suggests that the solution to most information problems comes with the use of lateral relations. These 'flattening' devices reduce the hierarchical structure and enable uncertainty to be reduced by closer working. He proposes seven ways of improving information management. These are, in increasing order of complexity:

1. Utilise *direct contact* between managers
2. Establish *liaison* roles to link two departments which have substantial contact.
3. Create temporary groups called *task forces* to solve problems affecting several departments.
4. Employ groups or *teams* on a permanent basis for constantly recurring interdepartmental problems
5. Create a new role, an *integrating role,* when leadership of lateral processes becomes a problem.
6. Shift from an integrating role to a *linking managerial* role when faced with substantial differentiation.
7. Establish dual authority relations at critical points to create the *matrix design.*

Considering this work was completed 20 years ago the relevance is still powerful as many of the arguments of Business Process Reengineering require this radical change. On many projects there are elements of the above but no clear strategy underpinning them. The significant project management challenge facing the modern construction industry is the establishment of channels and procedures for carrying this out. The framework in which this information processing function operates is established at a strategic level by the principal project players. Following their lead, tactical systems will be where the majority of key information flows with, for example, key decisions being made, such as the type of construction systems to be employed. Finally the bulk of information will be at the operational level where details, clarifications and explanations are communicated between those either responsible for or actually engaged in carrying out the work.

In such a light, this research has sought to establish what activities actually take place during the earliest stages of the development of an important element of a new construction project. The results have demonstrated that the involvement and subsequent contribution of many different actors is very important and indeed often crucial for a successful outcome. Where the strategy developed at the outset is robust then there is scope for a coherent system to be established which enables information to be generated, processed and transmitted to the right parties at the right time. If the initial strategy is not robust or has not been clearly defined then there are many areas where future problems can arise. Given this perspective, the following sections will consider the contribution which this research has made to this area.

11.2 The established knowledge base

Examining the literature on the areas of design, project management and the recently introduced theories of Business Process Reengineering clearly demonstrated that the area of interest does not represent a significant part of the existing literature. From philosophical arguments about the theory of design to highly technical approaches for managing time and risk, the area of information management in a project context has not been a focus for established texts on design and project management. Much useful work has been generated in the area of design on the understanding of how designers function, their interaction with clients and other professionals and ways of managing aspects of pure design (see chapter 2, section 2.3) yet there is little on how complex design as found in construction should be managed for project success. The developments in the field of design, moving from manual systems to computer based ones, have enabled the globalization of design development to take place, particularly when this new technology is used in conjunction with high speed data communications. The ability to transmit design information around the world where it can be developed and enhanced and transmitted back all within 24 hour periods is a significant development. These changes have been explored by the literature on design but there is a fundamental gap on how to effectively manage the activities for improved performance.

Such a gap in the knowledge base is exaggerated by the dramatic increases in the speed at which designs can be progressed, providing even more reason why the management of this information should be pre-planned. These changes to an already important area would lead one to expect that the literature on project management would look at information management, particularly as it relates to the design stage, in more depth. The general failure to consider the project from this perspective until recently, gives a possible indication of one of the reasons why, despite the large body of literature, there is still a failure of the majority of projects to deliver all that is expected of them. The development of project management as recorded in chapter three (see section 3.2) came from a systems based culture and developed along these lines, with much emphasis given to the solution of partial problems associated with the management of time, cost and, most recently, quality. It has only been the continued failure of projects to succeed, despite the use of increasingly complex analytical tools, which has focused attentions on the 'softer' issues associated with the creation of teams, strategic management, and concentration on meaningful communications (see chapter 3, section 3.9).

Business Process Reengineering (BPR) purports to offer a radical new way of considering business activities. A careful review of both the elements which underpin the BPR theory (see chapter 4, section 4.4) and its use clearly indicated that the main area of application had been in steady state environments which enabled the extensive planning stages necessary for successful BPR. The question of whether the theory of BPR could be applied to the highly dynamic project environment was one which the literature had not recorded. A prerequisite for any BPR exercise was the clear understanding of the existing process (see chapter 4, section 4.4.3). If the process were the management of design information then the underlying process involved needed to be mapped. As there was evidence which recorded the problems that this stage caused for companies who were operating in a steady state environment, where the process was contained within one organisation, the challenge was to be able to understand the process of design information management on complex projects. The literature on BPR indicated that this was crucial before attempting any reengineering exercise. The recorded high incidence of BPR project failure has been attributed by many commentators as being due to an over eager enthusiasm for embarking on a reengineering exercise without fully understanding what the existing situation is in the detail necessary. Another significant problem has been the failure of the most senior management to have the strength and courage to follow through with such radical and potentially disruptive changes. Although some way from being able to suggest a full BPR typology for construction projects, it is clear that the existing processes need to be fully understood to enable the fundamental questioning to take place. In particular, the process of managing information will be crucial to any radical improvement.

The literature on design suggested that this process was not clearly understood and had become a less active area of research, with attention focusing on technological issues and psychological approaches to design. The literature on project management is moving towards a recognition of the importance of human factors in project management, having almost exclusively focused on the role of systems and IT. The burgeoning body of literature on BPR provides clear evidence of the importance of this stage but does not provide much assistance in understanding this process in a highly dynamic environment such as that found on construction projects.

11.3 To change the prevailing view from the construction industry

There is a widely held belief that the early stages of construction project management, involving the design development, are incapable of significant improvement. The quote which is used at the beginning of this work (chapter 1, page 12) is reproduced again here and is considered in the light of this research.

> 'Architects are expected to produce working drawings and the builder is expected to carry out works in accordance with such drawings. The structural engineer relies upon the manufacturers to design the connections for the steel frame. The services engineer expects a subcontractor, appointed after the builder, to prepare all installation (i.e. working drawings). *Design co-ordination before construction starts is therefore impossible and ad hoc alterations on site are inevitable....'*.
>
> Extract from a quote from Mr. James Nisbet, former President of the Quantity Surveyors' Division of the Royal Institution of Charter Surveyors, quoted in Sir Michael Latham's final report 'Developing the Team'. (1994)

The above situation occurs frequently, with many of those who work on construction projects recognising the 'cart-before-horse' syndrome. Yet this research has indicated that where there are different attitudes, objectives or constraints from those commonly found, there is the possibility of achieving substantial improvement. The key to this change is the client and, by extension, those advisors to the client. The above quote does not mention the client and this is reflected in many management books aimed at the construction industry. This glaring oversight is the cause of many problems, with those professionals operating in the industry often excluding the client from the process of project management whilst at the same time lamenting the problems the client causes through indecision, delay or changes required.

Focusing on the area of information management, the client's influence on the proceedings can be fundamental. Briefly considering the four case studies detailed in this work, and therefore considering the façade in particular, allows an insight to be gained into how information, and the design in particular, is managed. The Helicon project (chapter 9) is a clear example of where a client's vision and faith in the key professionals working on his behalf to design and construct the building led to the establishment of a highly competent team of individuals who developed a design which was technically innovative, yet delivered within budget and on time. The D10 project (chapter 8) again demonstrated that a client with a clear set of objectives can provide the necessary management motivation to ensure that the project is successful. This project was highly unusual as it was subject to intensive external constraint. The determination and resolve of the project team were tested but a consequence of this was the buttressing of the design and the involvement of the correct specialist subcontractors.

Conversely, the two pharmaceutical projects demonstrated that clients who have an overriding objective - the minimisation of cost based on the lowest competitive bid - can lead to sub-optimal solutions. On the Glaxo project, the original insistence on lump sum competitive bidding for the trade contractors (see chapter five, section 5.16, part d) led to the type of scenario given in the quote above, with the resultant delay, confusion and expense. The problem was resolved by allowing the designers the flexibility to select the most suited components and then seeking the most suited contractors to install them. The SC1 project represented a complex construction project which was compounded by additional factors. Focusing on the façade, the interposition of senior client managers, outside the project management group, led to the rushed addition of work to a tender which was already being considered and which allowed the client to become more dominant in the decision making. The final decision to appoint a trade contractor was made primarily because of the discount offered, which should have been offset by the risks that were being taken in appointing a new and untried company, to carry out a very large amount of complex work in a short period of time.

By discussing the ramifications of such decisions at a stage before the design has taken place, the possibility exists of gaining improvements in the time it takes to successfully complete the design as well as providing an opportunity to discuss ideas with those who will be responsible for installing the elements of work, ultimately leading to the possibility of value engineering types of design improvement.

This last point was indicated as being a possibility on the SC1 project (see chapter 7, section 7.5). The influence of the trade contractor's designer at interview stage suggested that a far better product could be achieved while staying within the existing cost parameters. This potential result, a clear demonstration of the aims of value engineering, was obviously advantageous. The combination of uncertainty and complexity, which are always present to some degree in construction, were higher than would normally have been expected on a project of this scale due to the use of a recently acquired company who had not been used by the parent company, whose reputation was a key factor. This uncertainty was compounded by the client's desire to maximise cost reduction by the introduction of substantial additional work with an associated requirement for a unit rate reduction. The advice to the client by the professionals engaged on their behalf was to be wary of compounding an already intrinsically complicated element of the construction with such a level of avoidable complexity and uncertainty. The realisation phase of the project justified this caution and created many additional problems with consequent costs, delays and quality problems.

The appointment of the correct professional team by the client is itself the result of the client understanding a number of issues sufficiently clearly to be able to make an informed choice. The correct team will be that which adopts the client's objectives and provides advice which enables those objectives to be clearly met. A lack of objectives by the client, or objectives which are not supported by the professional team, can lead to the type of scenario described by the Nisbet quote. With the correct team around them, the client is capable of participating in a process which integrates specialists at the right time and in the right way which maximises the likelihood of project success.

Allowing sufficient time to develop the design successfully is critical. Evidence from the case studies demonstrates that where enough time and resource is allocated then the design progresses along expected parameters. Conversely, where there is insufficient time or inadequate resource then problems can be encountered both at that stage and, more critically, during the latter construction phase. The D10 project demonstrated that the length of time taken to get the design fully approved, complicated by the involvement of English Heritage, meant that the design was fully considered which led to few problems during manufacture or installation. The remarkable success of the Helicon's façade during its obligatory testing is a testament to the effort and pace of the design development dictated by the architect's enthusiasm and passion for detail. Where insufficient time was allocated, as can be argued was the case on the SC1 project, where the design was progressed from the equivalent of a detailed concept to tender stage in 12 weeks, then there were noted problems in resolving design details and the coordination of interfaces. Focusing on the façade, it was only because there were additional problems with the trade contractor that there was an unexpected additional period where the design could be improved. The problems encountered on the Glaxo project, where incompatible CAD systems were unable to translate design enhancements, led to a confusing and problematical period which was only resolved by the imposition of a temporary moratorium and the manual updating and coordination of the design.

The factors which are important for managing the design are therefore wide ranging and need to be considered across all layers of the management hierarchy which can be equated as being at the strategic, tactical and operational level. Although it would be naïve to think that such issues as tendering strategy and a design programme would not be considered, it is the combination of issues, all of which would affect the performance and success of the final construction but which take place before site activities start, which need to be considered in a unitary, rather than a partial way.

11.4 The value of this research

The complexity of managing project design has long been acknowledged as vital to ultimate project success but has been considered too difficult or controversial to be managed as a separate task. But with construction projects still failing to meet the expectations of clients or external critics it is timely that detailed investigation take place The problem of managing information increases with project complexity and therefore it was complex projects that were selected as being where most could be learnt.

The literature study failed to provide a satisfactory answer to the issues which had been raised and, with a lack of established and accepted knowledge to fall back on, the research was exploratory in nature, seeking to find out what was actually happening on real projects. This qualitative based work used a relatively novel methodology as it offered the potential to compile data from individuals to build complete models of the project. The detail which such focused research was able to capture has been a great asset, with many initially idiosyncratic stories being able to be explained by fitting individual contributions into a coherent whole. The subsequent analysis of the data has provided new insights into what are important issues for the managing of information on projects.

Having established the desire, the critical areas for the research were to define the area sufficiently to enable a valuable piece of research to be carried out which was capable of being successfully completed, given the resources available. The use of a pilot case study (see chapter five) allowed the full gamut of issues to be addressed, while at the same time recording the leading edge of management systems and procedures used in the UK at the time. The complexity contained within this substantial preliminary work identified the need for the subsequent work to focus on an element of a project to study in depth. The façade was chosen for its complexity and importance, as described in chapter six (section 6.4). The selection of the three projects used for the case studies was partially reliant on serendipity, partially on contacts within the industry, and was also due to keeping a constant vigil for active projects which met the research criteria. The cooperation necessary from the individuals involved on the projects was considerable and much valuable data was collected. This data was used in a novel way (see chapter 6, section 6.8) in that it was entered into software specifically developed as a decision support tool. Using the software, and the methodology of cognitive mapping which underpins it, a unique experiment was carried out which explored the possibility of trying to unravel complex data in a rigorous way which yielded a more objective insight into the reasonably opaque area of design management.

11.5 The added value of the methodology

The use of a traditional qualitative case study approach as used to record the Glaxo project enables considerable data to be collected and summarised, as can be seen in chapter five. The use of such a methodology, although valid, is open to criticism associated with rigour, completeness and capacity to be generalised. Although the Glaxo case study was thorough, it considered issues at a general level which diluted much of the data's power. As a piece of primarily investigative work, this case study achieved much, as not only did it cover a wide range of important issues, but it also enabled some clear recommendations to be drawn. It was felt, however, that there was far more potential for this type of enquiry. The use of cognitive mapping was proposed because of its lack of prescriptiveness, its data integrity and, with the use of modern software, its ability to handle large amounts of information. The application of this problem-solving type of methodology to an area where there was no problem *per se* presented new challenges. The results of this experiment have been recorded in chapters 7-10 and reveal a great deal about the area of interest both in detail and at a summary level.

This ability to analyse the data at varying levels, whilst still being able to keep a perspective, is one advantage. A more tangible advantage is the way in which the creation of cognitive maps enables a wide range of interconnected issues to be dealt with in a different way. The power of this approach has only been partially tapped in this research as the maps were created after thorough interviews were conducted and not in the presence of the interviewee. Although this has been discussed elsewhere (see chapter 6, sections 6.11-12) the ability to mimic the cognition of individuals when articulating their understanding of such a complex area is a powerful tool for the researcher in gaining a totally clear picture of what has, or is, occurring. The subsequent analysis of the maps, using objective methods, brings forth results which were not always expected. The most important benefit was the way in which areas that would normally be ascribed as being unrelated were clearly related. This appreciation of the complexity of interrelation was a direct result of the use of the methodology and one which, although possible, is not as apparent from the Glaxo case study.

A final area where the use of cognitive mapping, as used in this research, was advantageous was the ability to integrate different individuals' contributions, building an increasingly complex picture. On all three projects a deep understanding of the issues was possible to the researcher through the use of cognitive mapping and, it is argued, that were this to have been action research, then recommendations were possible for improvement. If the technique were to be used as a consultancy tool, which is where it is normally employed, then it is clear that the joint creation of the original maps, together with the subsequent analysis, would create a very clear insight into the range of issues which constitute the area to be addressed. It is then a less complex problem to find solutions for, using the armoury of existing tools and techniques available from both project management and design.

11.6 Generalising the main findings for the Construction Industry

The primary objective of the research was to understand what comprised the design process. The results drawn from the case studies, and reinforced by the literature, are that the process cuts squarely through all aspects of a project and affects all functional departments of the project management organisation. As the product of the construction industry gets more complex, so there is a corresponding need for the process which delivers that product to become more effective and efficient. The management of the design of the façade has allowed a valuable insight into what is involved, from the client's initial desires and objectives, through to the influence of the external agents and authorities.

The graphic depiction of the interrelatedness of the elements which constitute the management of the design is itself valuable for those involved in project management who need to be clear on the complex challenge which faces them. Such evidence is normally anecdotal in nature and therefore any objective data which supports the view should be welcomed. The loops discovered in the course of the research need further investigation as their impact is believed to be important generally. From the construction management viewpoint, the presence of loops reinforces the need for a coherent management approach moving from a wholly functional demarcation to a structure based on specialist teams operating on particular elements of the project from inception to completion. This team working requires a coherent structure which allows for functional specialisation, which professional institutions require whilst maintaining a longitudinal approach to managing the individual elements, cross referencing where necessary with other teams or specialists. By considering the project from this viewpoint a more holistic solution to the myriad of problems is available which avoids the pitfalls recognised generally and typified by the quote given at the beginning of chapter one and repeated earlier in this chapter.

In addition to the establishment of complex interrelationships, this research can make some clear recommendations which are likely to substantially improve both the product and the process. These recommendations will be considered next.

11.7 Formulation and communication of the objectives and strategy for the project

Once a client has established that they need to construct or refurbish a building or facility they will, in the vast majority of cases, need to employ the services of external companies or individuals to work both with, and for, them. From the earliest opportunity a clear strategy needs to be developed by the client, with the assistance of a professional representative if necessary, firstly by generating a clear set of objectives for the project. The formation of the objectives should then be used to explicitly establish a strategy for the project. The strategy will identify all the key factors which will need to be managed so as to lead to the fulfilment of the stated objectives. The project should have a consistent set of objectives and strategy prior to the commencement of the following stages of design and construction. The objectives and strategy are often considered as being routinely carried out on projects but it is clear from the case studies that the quality and quantity of the effort which goes into this stage can vary and this can have a direct impact on the project's ultimate success.

Drivers for the establishment of the objectives and strategy can come from the client organisation's own internal procedures which may require extensive submissions to senior management in order to receive Board approval and obtain the budget. The more rigorous the requirements for this stage, as demonstrated on the Boots D10 project, the more likely it is that many key questions will be asked and answered. The increase in information resulting from the identification of objectives should be used to feed into a strategy for the project. This strategy will require the involvement of construction professionals, users, client management representatives and the project managers from the client organisation who will have responsibility for the project. This clear beginning to the project can be seen as the start of the *process* of management which will continue into the active use, reuse and ultimate refurbishment or disposal of the built facility.

11.8 The identification and selection of the most suitable team of experts

The use of consultants from the construction industry, including design specialists, is increasingly important. In the more commercial world since scale fees were abolished there is less certainty in the expectation of service provided by consultants. The use of Design and Build, Design and Manage, and Construction Management forms of contract, increasingly operated within a Guaranteed Maximum Price framework, have placed considerable pressures on all parties. This pressure to integrate diverse skills, systems and personnel is at the core of the challenge for the management of the design. The second stage in the process, having established the objectives and a strategy, is to consider which companies and which individuals to employ on the project. The selection will vary according to the specific requirements and timing of the project, however, there are some principles which should always be followed. As a central consideration there should be the desire to maximise the opportunity to bring integration and experience to the project. The integration sought is both at a personal and business level, with the attitude, personality and history of key individuals being important, while at the business level, the type of systems used, business background and resource base need to be considered. The experience of the businesses should not be limited to the necessary professional experience on projects of a similar nature. As important is the experience of working with other members of the team who will work on the project. Where new teams are created, there should be a willingness by the team members to demonstrate an enthusiasm for establishing a *rapport* with other coalition members. This area is increasingly recognised and leads some clients to seek consortia bids from groups of consultants who select each other. This philosophy was used by Glaxo and can be considered as the success of the PAE (see chapter five) with the integration of designers from architecture and engineering working together on individual buildings. On the Helicon project the selection of firms who had previous experience with either the client or each other added significantly to the speed and reliability of the design's development.

The more complex the requirements for the project, either in technical terms or those imposed by management, the more important it is that the expertise necessary is brought on board at the earliest opportunity. This point in particular has some fundamental implications as the need to integrate the specialist design input from the trade contractor requires a form of contractual appointment which would normally seem to limit the perceived commercial advantage of traditional competitive tendering. The arguments for traditional competitive tendering are clear and well established. The allocation of risk is straightforward, as is the transparency of the decision making.

However, there are many associated problems, particularly related to the onus it places on the design and specifications to be complete and error free. In the UK in particular, the development of a system which rewards low prices at tender stage has led to a secondary system of claims. Although workable, this system effectively thwarts project innovation and the development of mutually beneficial relationships.

The benefits of seeking best value and not lowest cost are that, from the time of appointment, a non adversarial approach can be adopted which, if fostered by the correct management systems and attitude, can lead to a better product, more effective and efficient process and enhanced margins. The cost of these benefits is the need for a far more thorough tendering process. Starting with the list of potential tenderers, research is necessary to establish clearly who is capable of fulfilling the project's requirements, then carrying out a thorough evaluation, including interviewing those designers who will have to liaise with counterparts in other design organisations. The dramatic events on the SC1 project indicate that the 'gut' feeling of those responsible for evaluating the participants is an important decision support tool, particularly if the evaluation panel has representatives of the designers and builders who will be working directly with the successful candidate organisation. The proactive approach from the PQS on the Helicon project suggests that such expertise exists currently.

The appointment of the consultants on a fee basis is subjected to the same issues, with a need to consider which individuals or teams will actually be working on the design and to ensure that the fee adequately covers for the provision of a full range of services with no obvious omissions. If this policy is adopted throughout then there will be a principle established which can be tailored to fit the requirements of either two stage tendering or nominated forms of contract. On the Helicon project, the use of competitive tender as a precursor to negotiations appeared to be an extremely effective method of ensuring that the client obtained the best service at the keenest price. The appointment of a main contractor on the basis of a comparison of key element prices, contained within the overall price, then a reconstruction of the price following detailed discussion and negotiation to remove all caveats, not only gave the client the most secure price, but also enabled the construction firm to be inducted into the culture of the project. This aspect of the process is significant and is one of the core components of project partnering which is currently the vogue in the UK industry.

An important aspect of the appointment is to try and maximise the useful overlap between appointments. On the Glaxo project the transition from concept architect to project architect was gradual, with both parties working concurrently for a considerable time. This was repeated on the SC1 project where the early design was carried out by both master planner and project architect. Considerable benefit is gained through this overlap, with different areas of design expertise adding to the completeness and accuracy of the design. If construction expertise is brought on similarly early then there is real potential to integrate the project's development to everybody's advantage. This philosophy, used on the Glaxo project, brought all the relevant parties together when there was the potential to have greatest influence at least cost. Where this scenario occurs within a context of contractual flexibility, which enables choices to be made at the most appropriate time, then significant advantage may be gained.

11.9 The need for compatible IT

The use of IT in construction is widely accepted, with even relatively small subcontracting organisations with design needs having access to CAD equipment and other basic computing facilities. It is seductive to consider the use of IT as the key to the solution of the problems associated with managing the information flow. Yet the use of IT should only be considered as an addition to the management system and not the basis of the system itself. Compatibility of CAD systems can be advantageous as time can be saved through the electronic transfer of information. The use of such media does, however, create its own management problems, as checks have to be in place to ensure that all parties are operating on the same current information. Much time and money can be wasted redoing designs or specifications if the base information was not the correct version. In a paper based system it is relatively straightforward to ensure that current information is used. Such straightforwardness is to be strived for in an electronic information based project.

Some of the most effective IT used on construction projects, particularly for design management, are the phone and fax. The speed and user friendliness of these reliable technologies are their greatest advantages and it is a development of these communication based technologies, in the form of the use of video conference facilities, where face-to-face communication and concurrent file access is used, that offers the most significant development in design management. This development, which is highly plausible, will become more widely available and cheaper to procure and operate as ISDN networks become more widespread and the technology allows wider bandwidth transmissions to carry data, voice and moving images. This will enable virtual co-location to take place with face-to-face communication possible when personnel are actually working in totally separate locations. The ability to transmit complex CAD files is already well established, as is the remote printing of the drawings. The use of three dimensional modelling, creating easily interpreted images from the original designs, offers the opportunity for users to understand the realities of the design. More benefit will be from the virtual mock-up of complex areas of construction to resolve clashes, detail requirements and interface sequencing, all of which are still considerable problems during the construction phase.

11.10 The establishment of a close working relationship between key designers

The use of IT, particularly the development of communication technology, needs to be placed in context. The use of this sophisticated technology would be far more effective for continuing a working relationship developed after the direct meeting between the designers so that an initial bond can be formed. This point is crucial, for the effective development of the design on complex projects increasingly requires the co-operation and interaction of many specialists. Within this diverse matrix of relationships there will be a few core relationships between, for example, service engineers and the M&E contractor or the architect and the façade contractor.

It has been demonstrated on all three projects that the personal relationship between designers from different organisations was at the centre of the design development. On the SC1 project this factor was clear as the AMEC architect and the Harmon/CFEM design manager developed a close working relationship which *ceteris paribus* was able to quickly solve complex design problems. The importance of the individuals working well together was reinforced on the Helicon project where the design problems created by the desire to create a technically advanced, energy efficient, landmark building led to an intensive period where the communication of ideas, their enhancement and the resolution of problems, required a clear and trusting relationship. This occurred and the resultant way that the design developed, based on frank and lengthy discussions and regular meetings, was seen as a major success.

This close relationship can be fostered through the pre-planned use of mock ups which act as a stage between design and construction. Although not featured strongly in the case studies, all four projects used mock ups and their benefit is greater than simply being able to examine the physical manifestation of the early design work. The added advantage is that it provides a focus for the development, and testing, of the relationships between the various disciplines who jointly need to develop the final product. In addition to those involved in the linear progression for each element, there is much advantage to be gained from coordinating the various elements which come together within a building. With the façade, these interfaces are, for example, perimeter heating, internal cladding and suspended ceilings. The opportunity to consider complex areas in the relative isolation of the mock up environment can reveal problems of understanding or reveal solutions previously not thought of. With the continued rapid development of 3D CAD modelling and virtual reality software and hardware, it is likely that realistic mock ups will be created within computers and tested virtually before resources are committed to construction.

11.11 The methods to manage the design

With the correct mix of individuals there is still a need to manage the way the design is developed. Of the myriad of options available, a structured regime of reviews should be considered as a central feature. Using this format the phases of the project, from initial inception through to commissioning, can be managed both to pre-plan activities as well as react to developments which have occurred. Using the pyramid analogy there should be an overall strategic review held at regular intervals which forms the summit of the pyramid. Into this review feed the results of increasingly focused levels of review which address particular issues. Figure 11.1 illustrates the principle.

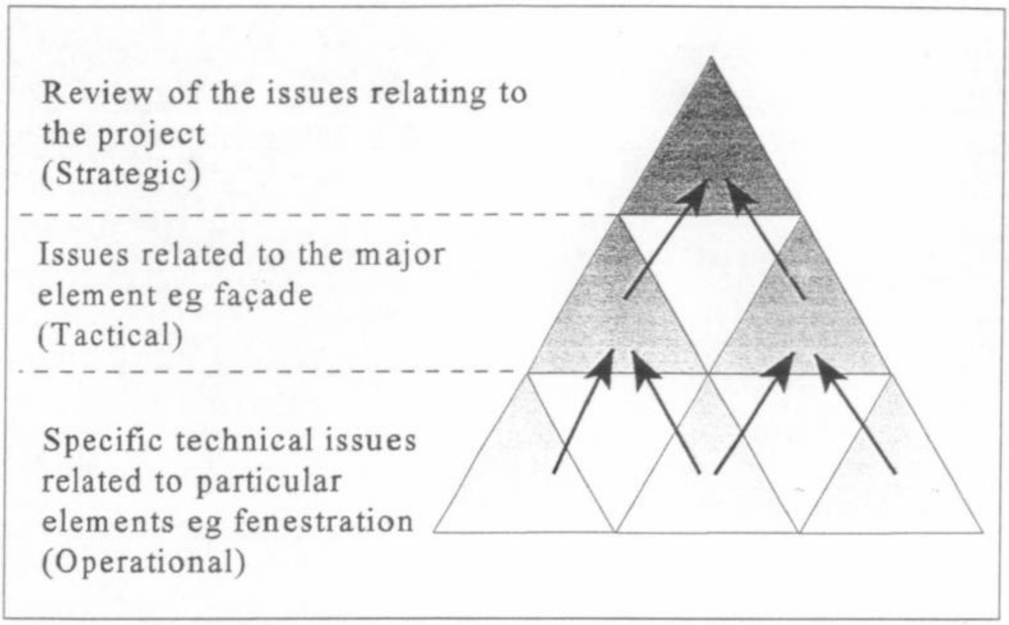


Figure 11.1 The levels of project review

Using the review as a vehicle for the management of the design there is the potential to clearly prepare the management of the design using the timing, participation and agenda for the reviews as the core tools. The timing of the various levels of review will vary, with the lower levels being held more frequently. Below these official reviews there would be meetings between individuals to resolve particular problems. The purpose of the reviews would be to formally draw together issues pertinent to the level of review. These issues would be to consider the actions and developments which had taken place up to that point, as well as to establish the next set of objectives or milestones to be achieved. Operating within the review structure would be individuals whose purpose would be to ensure integration between different elements and coordinate and standardise. Thus the technical issues would be addressed by those involved at the level of review most suitable to the problem, with only the most serious of problems being raised at the strategic level. This form of management worked well on the Glaxo project and was therefore capable of being used on very large scale projects as well as being easier to implement on smaller projects. Through careful planning in advance, the possibility exists to structure the management of the design through the various stages from briefing to design development by the trade contractors and then on into the construction phase.

11.12 Allowing sufficient time for the design to develop

Despite the dramatic advances in CAD technology, the issues of coordination, buildability and validation require sufficient time to be completed so as to achieve the levels of certainty needed to manage the associated risk. Although it is accepted that there will always be pressures to complete projects in the shortest time, it is clear that rushing the design only leads to mistakes and omissions which will ultimately be discovered and will lead to delay, increased cost and sub-optimal solutions. On the D10 project the problems with English Heritage meant that there was ample opportunity to completely consider the design, which in turn led to few problems later on. The use of reviews with English Heritage additionally reinforce the point made earlier in section 11.8, as the focus on formally presenting the proposed scheme meant that many aspects of the design were considered.

11.13 The overall process

Using the information contained within the previous sections above, it is possible to draw all the issues together and present a view of the overall process. This process, originally envisaged at the outset of this research to manage the design stages, is expanded to capture the whole project management activity. It is useful at this point to consider the process in terms of the gap analysis model presented in chapter two. This model incorporates the cause and effect features used in cognitive mapping, as well as demonstrating that it is the communication of the expectation and perception which is import~nt. Using the principles of this framework, the diagrammatic presentation of the process is offered in figure 11.2 on the fo''owing page.

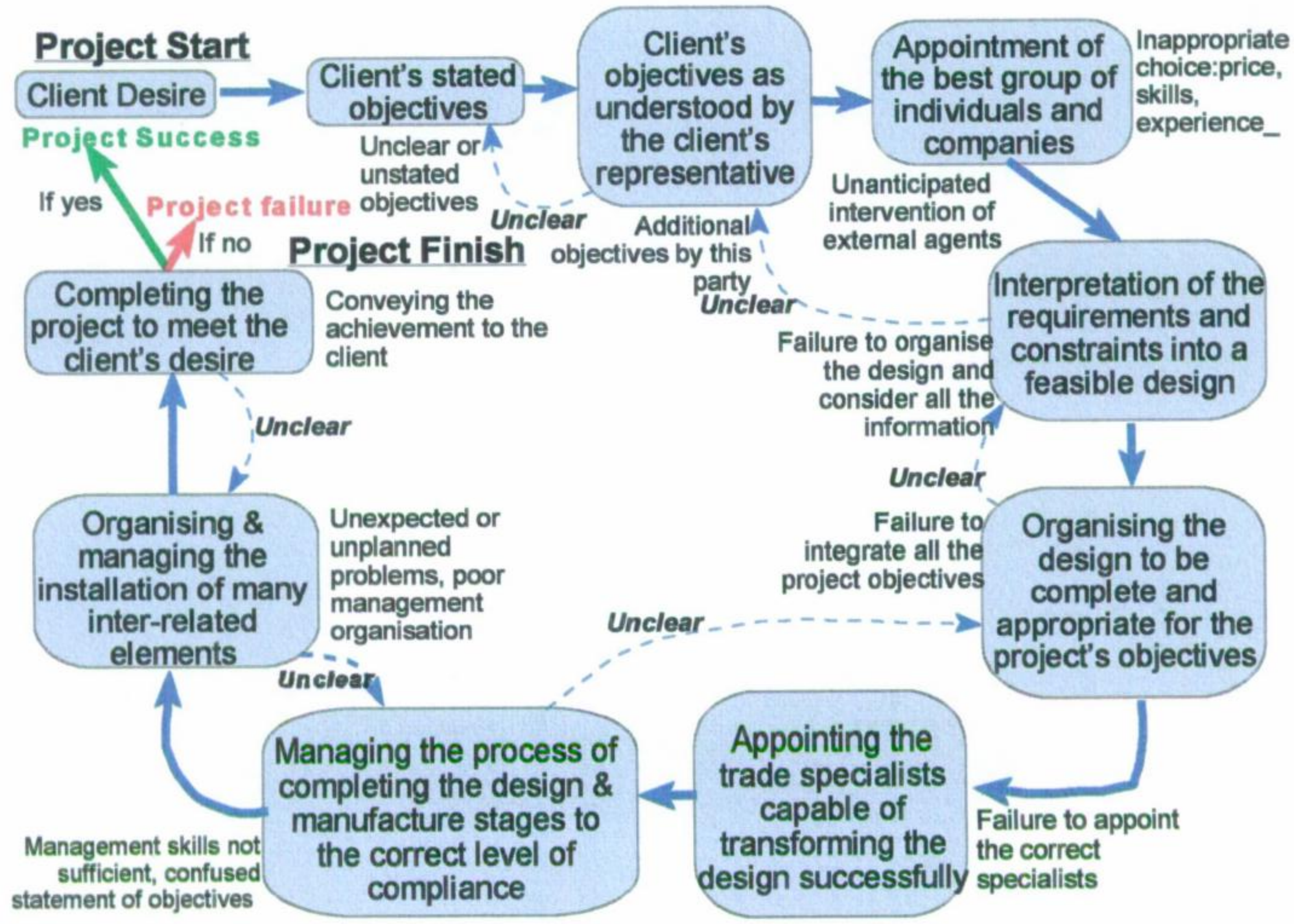


Figure 11.2 The project process

Figure 11.2 attempts to convey the salient points drawn from the research and presents it in such a way that insight is gained into possible management solutions to the complex process. In principle there are three components of the diagram. Firstly, there are the stages of the generic process, with a project start and a project finish. These stages are contained within boxes and lead from client desire to project delivery. Secondly, the issues which are possible disruptions to the smooth flow from one stage to the next are noted next to each box. Finally, the important issue of clarity is included between all key stages. Where there is a likelihood of the information contained within a stage not being clearly communicated then a loop is drawn indicating that further communication is necessary. The successful completion of each stage therefore represents a reduction in uncertainty and an increase in clarity for project information. Moving along the project lifecycle takes project players through all the stages represented by the process map to a distinct conclusion. This will culminate in the delivery of a completed facility. If the last box on the process map is treated as a question, then two answers are possible; either yes the project meets the client's desires, or no it does not.

The term 'desire' is used because it conveys the objective aims associated with time and cost, with the complexity of issues associated with quality and other more esoteric aims.

The successful project will be one where the client is satisfied with both the product of the project as well as the process which has created the project. This is far more likely to occur if the client feels that all the other project players are 'in tune' with their aims and objectives and are operating as a cohesive unit. Although it is possible to achieve the end product within a more adversarial environment, it is likely to be a less efficient and satisfying state of affairs.

11.14 Future Developments

This research, carried out on understanding the design process, has captured valuable data on the complexity and diversity of this important area of the construction industry's activities. The insights gained into this area suggest that there are a number of issues which clients of the industry and managers of projects need to consider if they wish to improve the effectiveness and efficacy of construction projects

For those engaged in continued research into this area there are some equally challenging opportunities. The exploration of the issues carried out thus far has used a methodology which offers great potential to both further explore the complex world of modern project management as well as moving onward to develop diagnostic and consultative tools which can improve understanding and performance.

The use of cognitive mapping has been successful in terms of the research objectives. In addition, it offers significant opportunities for developing strategies by those actively engaged in project management. This technique is well established as part of management science, but its use in construction project management has been limited. Where the communication of information is vital, and where this information itself is dependent upon the perception of those individuals taking part, then the ability to ensure that perceptions are correct should be seen as valuable. Indeed the very act of investigating these perceptions through the process of creating cognitive maps would be advantageous.

For future work of this nature it is accepted that there is a very strong argument for the direct creation of the cognitive maps at the time of interview. The benefits of ownership, immediate validation and coherent development are all valuable assets. The benefits accrue firstly to the researcher, as the quality of the data becomes irreproachable and the maps created are the considered product of an investigative process carried out mutually. To the participant the value of undergoing the exploration of their cognitive process is the clarification of thought and issues and a realisation that complex areas can be considered in a new way. For research into areas such as that of design management, the skill of being able to map directly, rather than relying on interview transcripts, is therefore an almost fundamental requirement.

The development of the software to enable content analysis, through a methodology such as Principle Component Analysis, is being considered by those at the University of Strathclyde. Such an ability to examine the actual wording used in the construction of the cognitive maps would be a useful additional tool for the exploration of such complex areas as design management, or indeed project management.

Following on from this research, the discovery of loops in the process of design are an intriguing prospect worthy of further consideration. The possibilities for their explanation have been considered earlier in this work (see chapter 10, section 10.7-8), but it considered that the likelihood of the loops being linked to the iterative nature of design, together with accepted complexity and inter-related nature of the problems, provide a hypothesis on which future research can be based. The use of direct mapping, together with follow-up interviews to discuss the meaning of the loops, would be worthy of a research programme which, if applied across a complete project, would generate new data and knowledge on the management of these complex phenomena.

Widening the horizons, the area of design management, viewed in terms of this research, indicates that there is a new view of the project which sees beyond the traditional disjointed stages of briefing, design and construction and which requires research into the best ways of management across the heterogenous population which constitutes construction project management. If the construction project is seen as an open system, influenced by variables both within the project as well as externally, then the scope for research into the most effective form of control and communication is vast. The advent of new information technology offers the real prospect, supplementing the traditional forms of communication and perception, and those in the area of research should be both trying to explore the possibilities and assist in the dissemination of this new knowledge. Design tools such as Quality Function Deployment and Taguchi Methods are all possible candidates for understanding how design can be managed, but will only be of value if they are considered in the correct context, namely one which is dynamic, complex and open to the influence of many participants. With a detailed exploration of this important aspect of management the prospect for future improvement which benefits all parties is significant.

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Appendix 1a

Methods for calculating Earned Value

$$\text{Percent complete} = \frac{\text{Quantity installed}}{\text{Quantity to install}}$$

→ Earned Labour = (Percent complete) x (Control budget labour hours)

The percent complete and earned value are calculated both for individual accounts and summary accounts, and are used to determine productivity, schedule performance and indicated total cost.

Productivity

Labour productivity is a comparison of earned labour hours to actual labour hours. Productivity is calculated as:

$$\text{Productivity} = \frac{\text{Actual labour hours}}{\text{Earned labour hours}}$$

If productivity is 1.0 or greater, the work is being carried out on or below budget. If less than 1.0 then the work is overrunning the budget

Estimate at Complete

The formally calculated projection of the total value and completion date for the project The values projected are extrapolated from the actual progress data entered. Where future progress is likely to be affected by exceptional information (for example, advance warning that expected delivery dates will not be met).

Estimate at Complete - Cost

Estimate at complete (cost) is determined by combining the actual cost per account and an estimate to complete cost The estimate to complete cost is evaluated monthly Productivity derived from unit rate analysis of completed work provides the best indicator of future work. If remedial or rework is necessary and this is of sufficiently large size then specific rework accounts would be established

Appendix 1b

The Work Breakdown Structure (WBS) is the hierarchical structure used to show ever increasing detail of the construction activities As a hierarchy, it is broken down into several levels with the top level being an overview and the lower levels giving ever more specific and detailed information.

Level 0 -	Milestone Schedule. Represents the total project.
Level 1 -	Master Project Schedule. Breakdown of the total project by management areas.
Level 2 -	Master Detail Schedule. Initially would essentially define construction disciplines by area for example. civil, structural, electrical, mechanical, etc. This level will ultimately take the form of a subcontracting plan and is therefore dynamic.
Level 3 -	Master Detail Schedule Represents the Elemental Work Package (EWP) level. EWP's are independent scopes of work which can be defined during scheme design. Typically an EWP scope will not change once defined EWP's will be combined to form subcontract work packages. The assembly of EWPs is expected to be dynamic, reflecting changes within the subcontract plan.
Level 4 -	Represents the discrete task within an EWP.
Level 5-	Subcontractor Schedule. Used in conjunction with the detailed schedule to provide complete detail of subcontractor activities.

Below is a chart which details the scheduling levels

	Type of report	Period covered by reports	Measurement	Information provided by	Frequency of report	Used for
Milestone Schedule WBS.2	Barchart 300-400 activities	Total project	Early values	GGR PAE LMK	Bi-weekly pre-construction Monthly during construction	Subcontract plan
Master Project Schedule WBS 3	CPM network 2 000-3 000 activities	Total project by Element Work Package	Monetary equipment material	LMK	Bi-weekly pre-construction Monthly during construction	Master construction/ schedule control budget cashflow % complete
Master Deta Schedule WBS 4&5	Network diagram 1000-1500 activities total	2-6 months	Labour by craft monetary equipment commodities	LMK area management	Bi-weekly pre-construction Monthly during construction	Window of total project
Subcontractor schedule WBS 4&5	Network diagram and/or barchart 200-300 activities	Total contract duration	Labour equipment commodities	Subcontractor	Depebdent on contract duration & level of activity	Specific sub-contractors

Figure Appendix 1b Project Management Tools

The above figure demonstrates the use the of various project management tools used to provide the varying information needs The use of cascade bar charts and Critical Path Management (CPM), in combination where necessary, provide the targets to be achieved. The ability to calculate the impact of any disruption and re-schedule if possible is also important in such a complex, dynamic environment where a number of exogenous factors remain beyond the control of the project management

The Master Project schedule is prepared to the level of Work Breakdown Structure 3 (WBS3) which gives the Elemental Works Package (EWP)

Master Detail Schedules cover a period from 2-6 months and are produced in sections or areas as information from the PAE becomes available

Intermediate Schedules can be composed of the following:

Short Term Schedules

Tender Subcontract Schedules

Subcontractors' bid schedules

Subcontractors' Schedules

Subcontractors' Construction Schedules

Two Week Look ahead Schedules

Internal Reporting Schedules

Appendix 1c

Details of Work in Progress measurements

Units Completed

The Units Completed method was used on tasks where pieces of work required the same amount of effort to complete. Trench excavating, placing concrete slabs, etc are examples where the overall activity comprises repetitious tasks. For example if the activity is to lay 5,000m^2 of concrete slabs and 3,000m^2 have been laid then the activity is 60% complete As many construction activities are of this type, this method would be expected to be the one principally used.

Incremental Milestones

The incremental milestone method is applicable to work having sequential sub-tasks. For example, the installation of a major piece of equipment could be progressed with this method.

Received and inspected	10%
Rough setting complete	45%
Final alignment complete	60%
Internals installed	90%
Full testing complete	100%

Start/Finish

The start/finish method is used on those operations where there is a definite conclusion to the activity, but where it would be extremely difficult to estimate how much of the activity had been completed prior to its complete finish Testing of systems is an example of such activity, where the testing may be straightforward or may involve unforeseen complications Until completed, it would be speculation to judge how much time or effort it would take to complete. Activities can be partially complete upon commencement so the measure is not necessarily from 0-100%.

Supervisor Opinion

The supervisor method is used for relatively minor tasks where developing a more sophisticated method would operationally unjustified. As this method is reliant upon individuals opinions it is not accurate and should only be used for the least important activities

Cost Ratio

The cost ratio method is used for tasks which are time based rather than on the production of measurable output. Project management, quality assurance, safety, industrial relations and dust control are all such items. The calculation for such activities is.

$$\text{percent complete} = \frac{\text{Actual cost}}{\text{Estimated cost at completion}}$$

Weighted or Equivalent Units

The weighted or equivalent units method of measuring progress is used where the task involves an overlap of sub-tasks performed over a long period of time. Installing exposed piping, structural steel or ductwork would all be activities which are suitable for this method. An example of how installation work can be earned in equivalent units would be:

	Unit of measure	**Quants. total**	**Equiv. Ft**	**Qty. install**	**Earned Ft***
Installing hangers	ea	200	80	60	24
Installing duct sections	ea	450	800	100	178
Installing dampers	ea	30	80	5	3
Leak test ducting	%	100	40	0	0
Ductwork summary	ft	1,000	1,000	-	215

$$\text{*Earned ft} = \frac{\text{(Qty. installed) x (equivalent ft)}}{\text{Quantity total}}$$

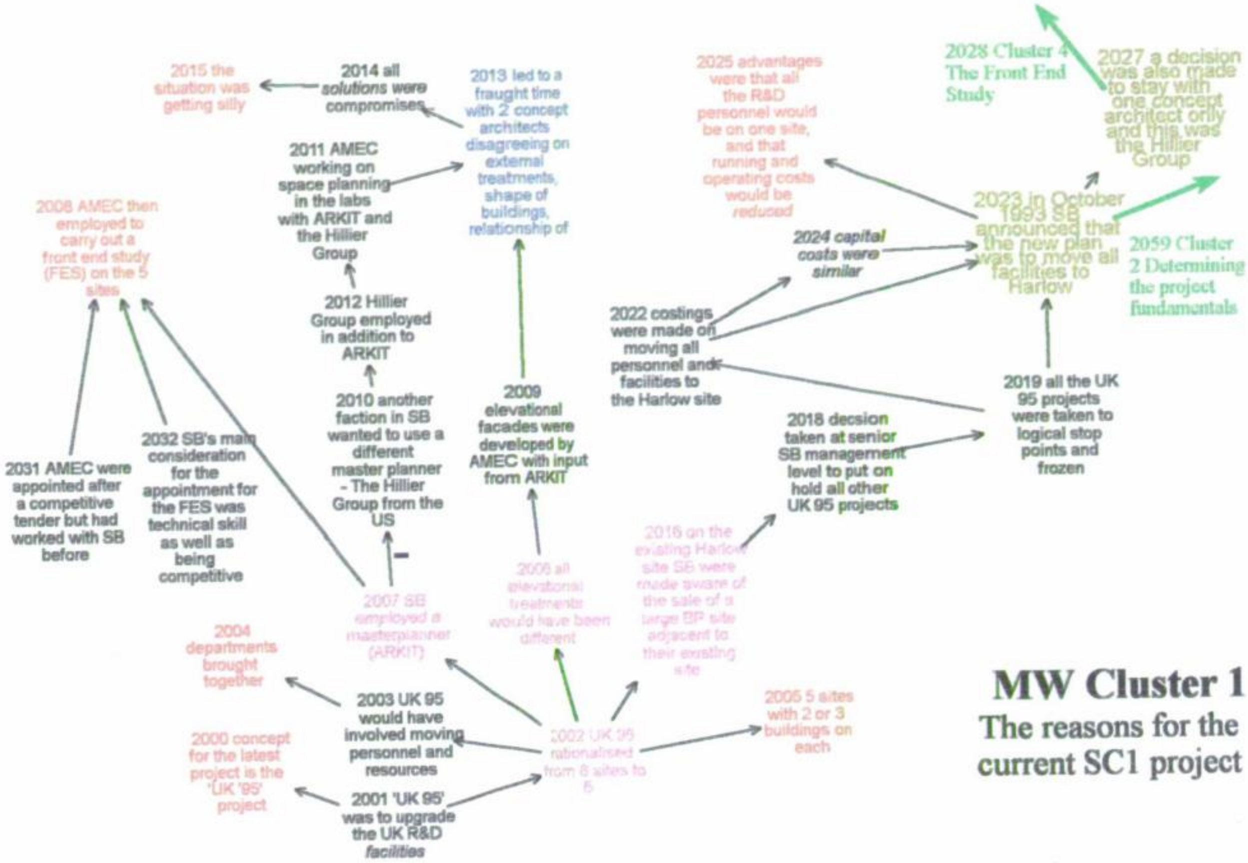
$$\text{Percent complete} \quad \frac{\text{215 earned ft x 100}}{\text{1,000 total ft}} = 21.5\%$$

Appendix 2-4

Individual cognitive maps

Note

The following diagrams use the same colour coding as featured in figure 6 6 with one notable exception. Green text is now used to indicate which other cluster and concept a particular concept relates and is connected to the green arrows which demonstrate the direction of the relationship.

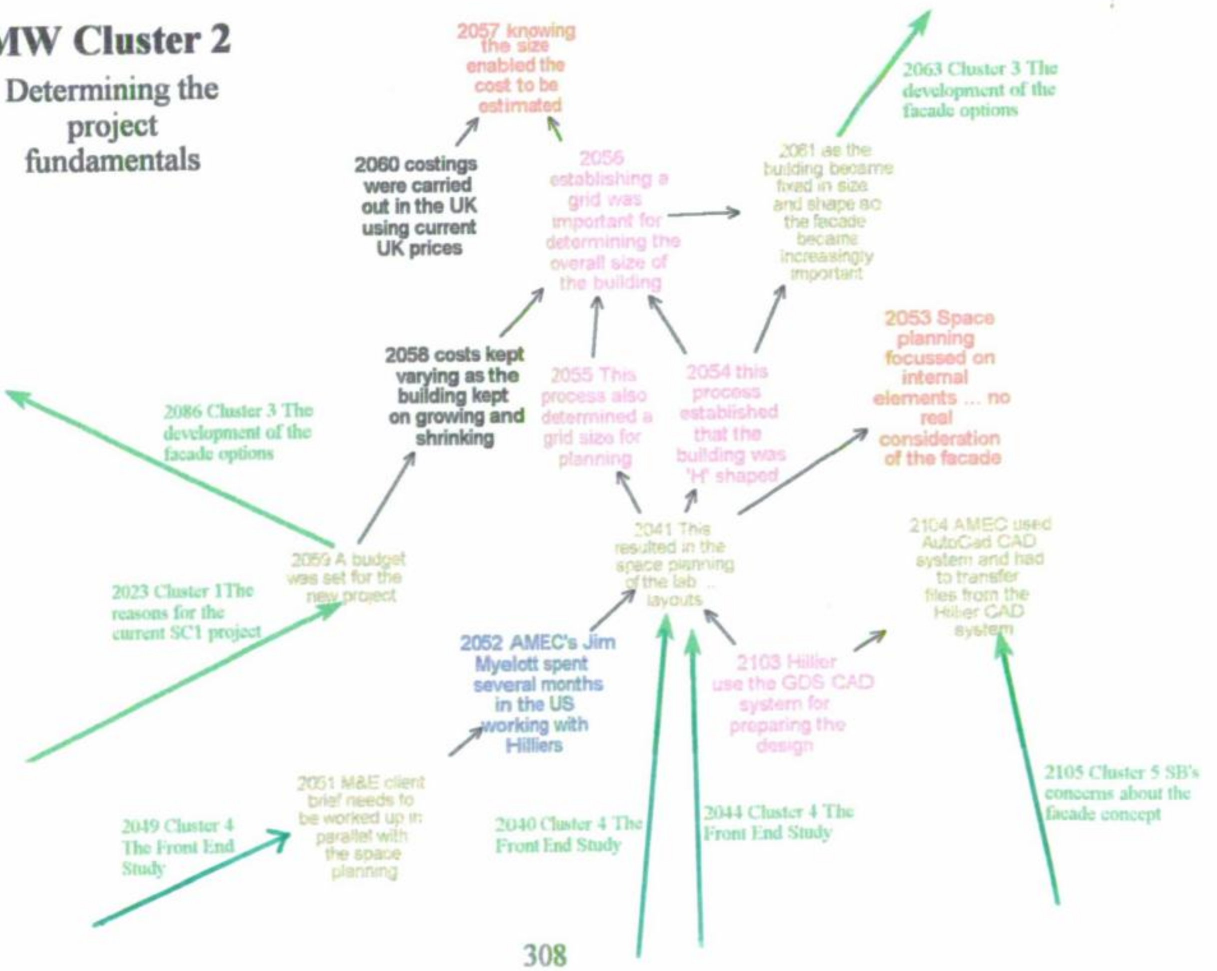


MW Cluster 1

The reasons for the current SC1 project

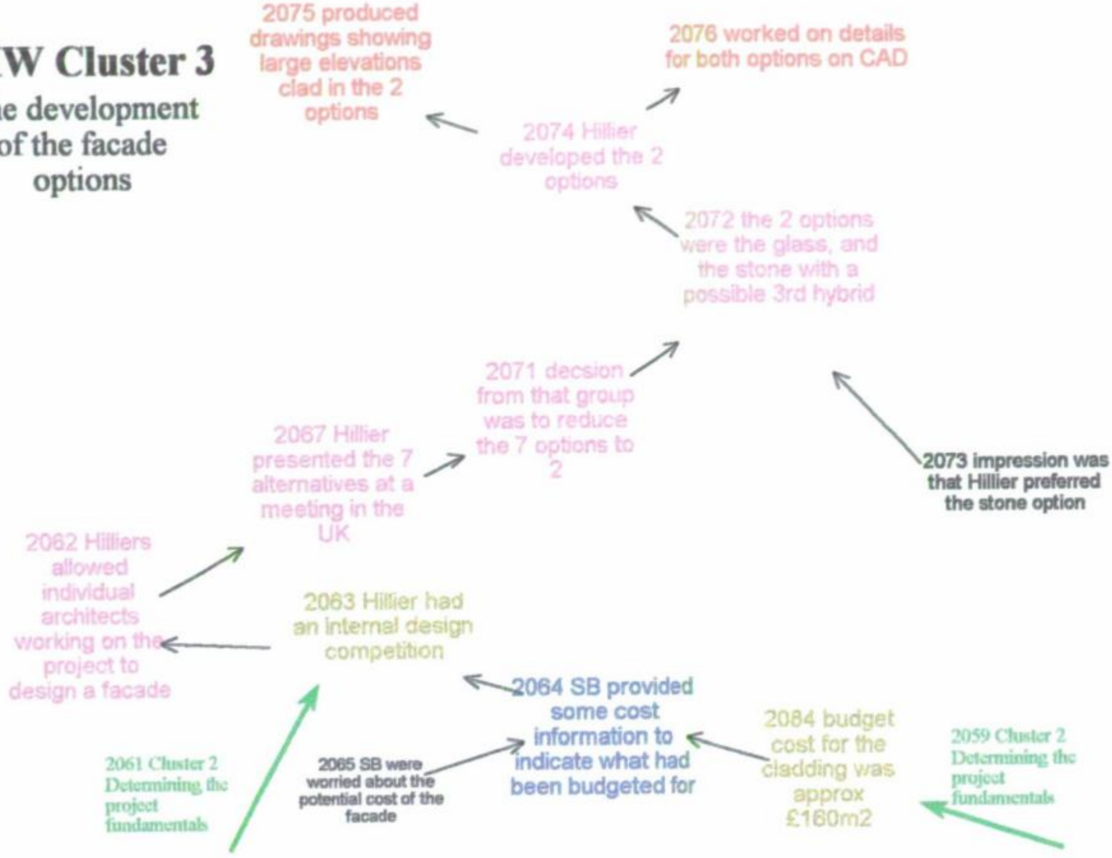
MW Cluster 2

Determining the project fundamentals

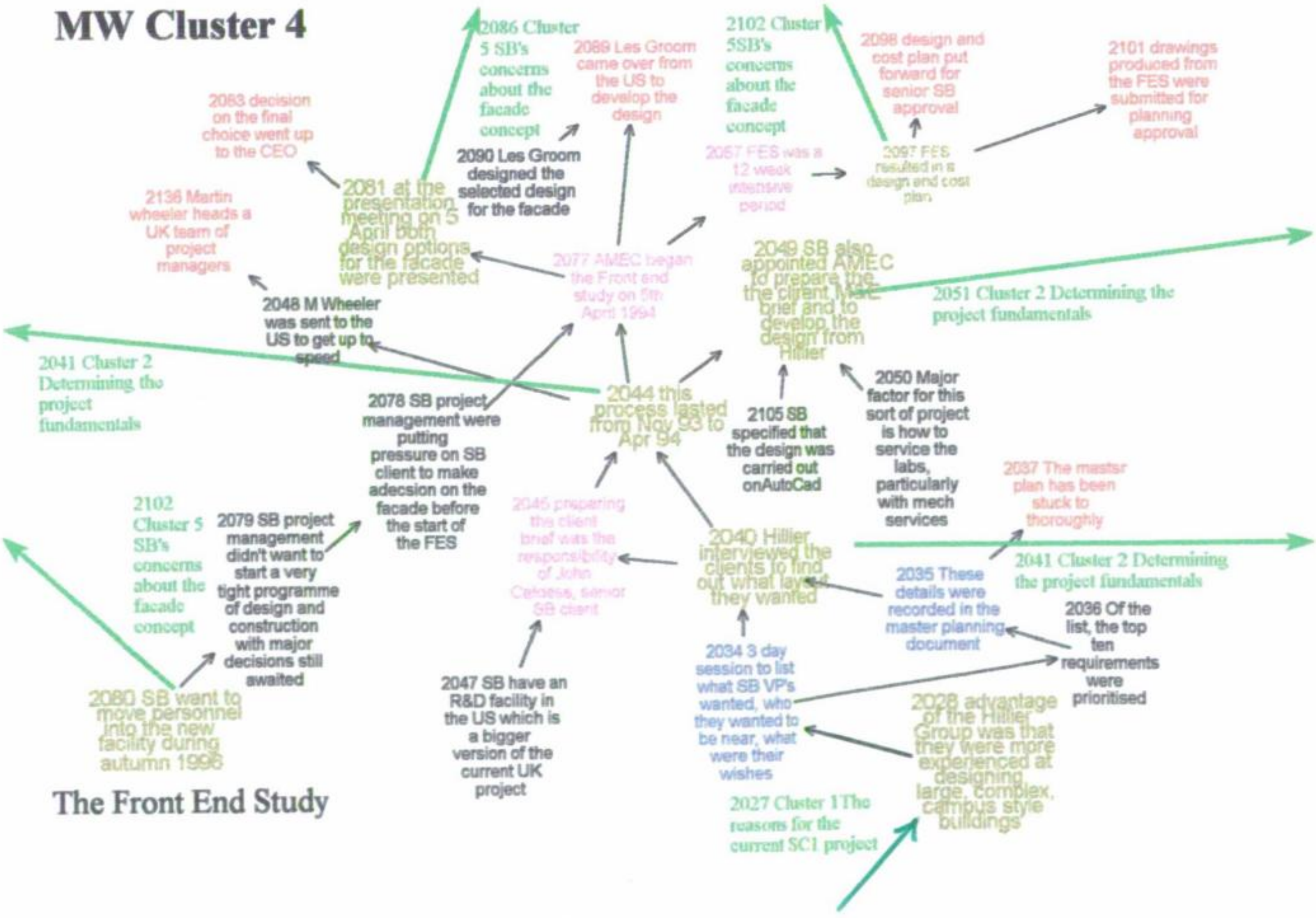


MW Cluster 3

The development of the facade options

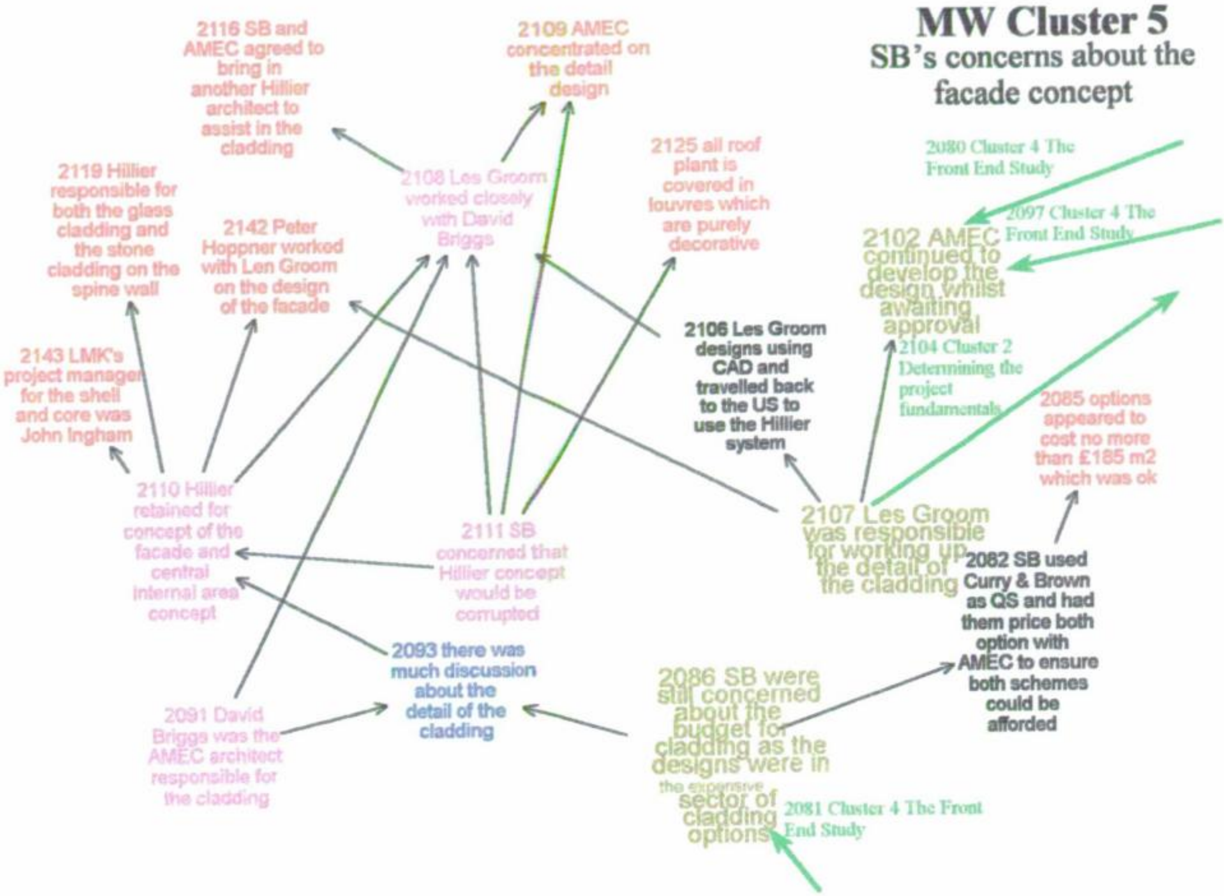


MW Cluster 4

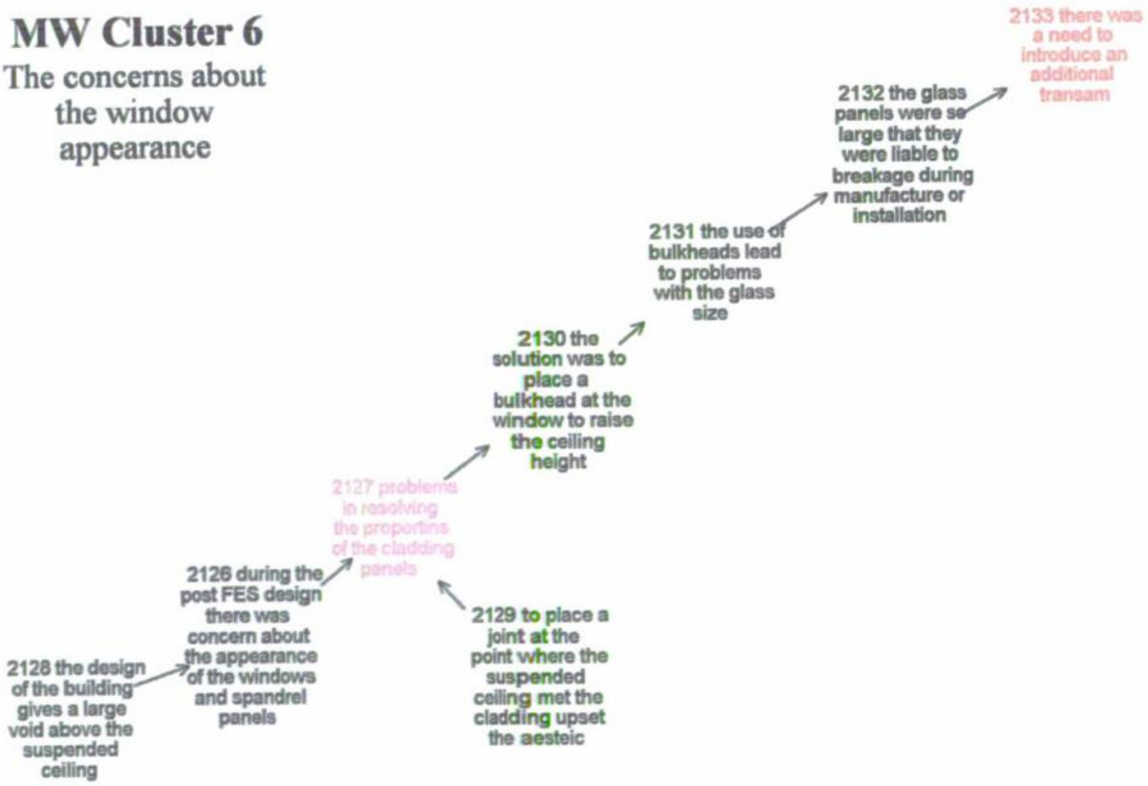


The Front End Study

MW Cluster 5
SB's concerns about the facade concept

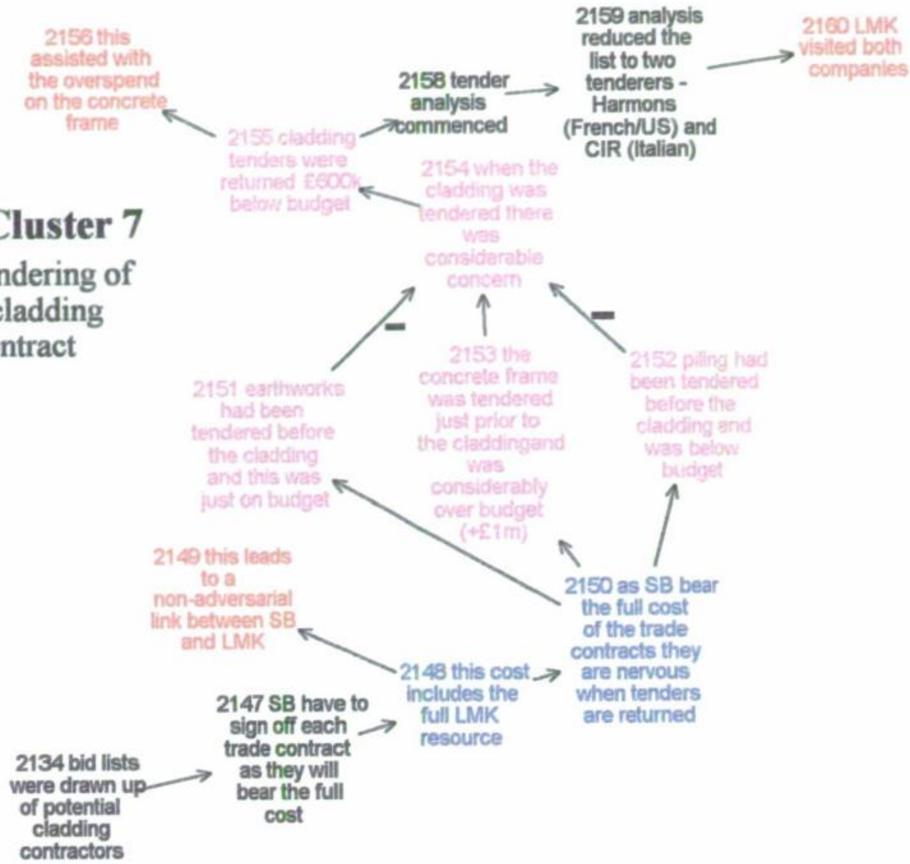


MW Cluster 6
The concerns about the window appearance



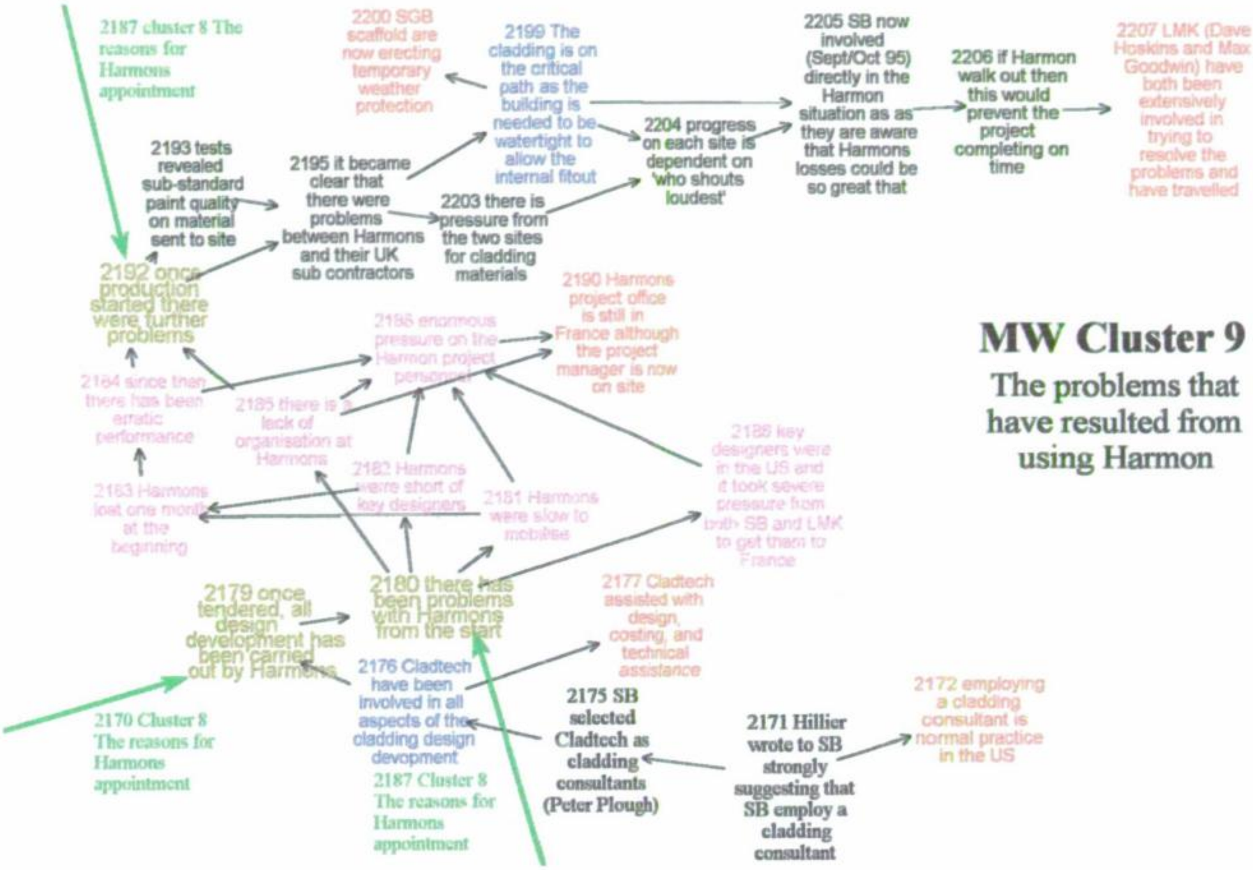
MW Cluster 7

The tendering of the cladding contract



MW Cluster 8

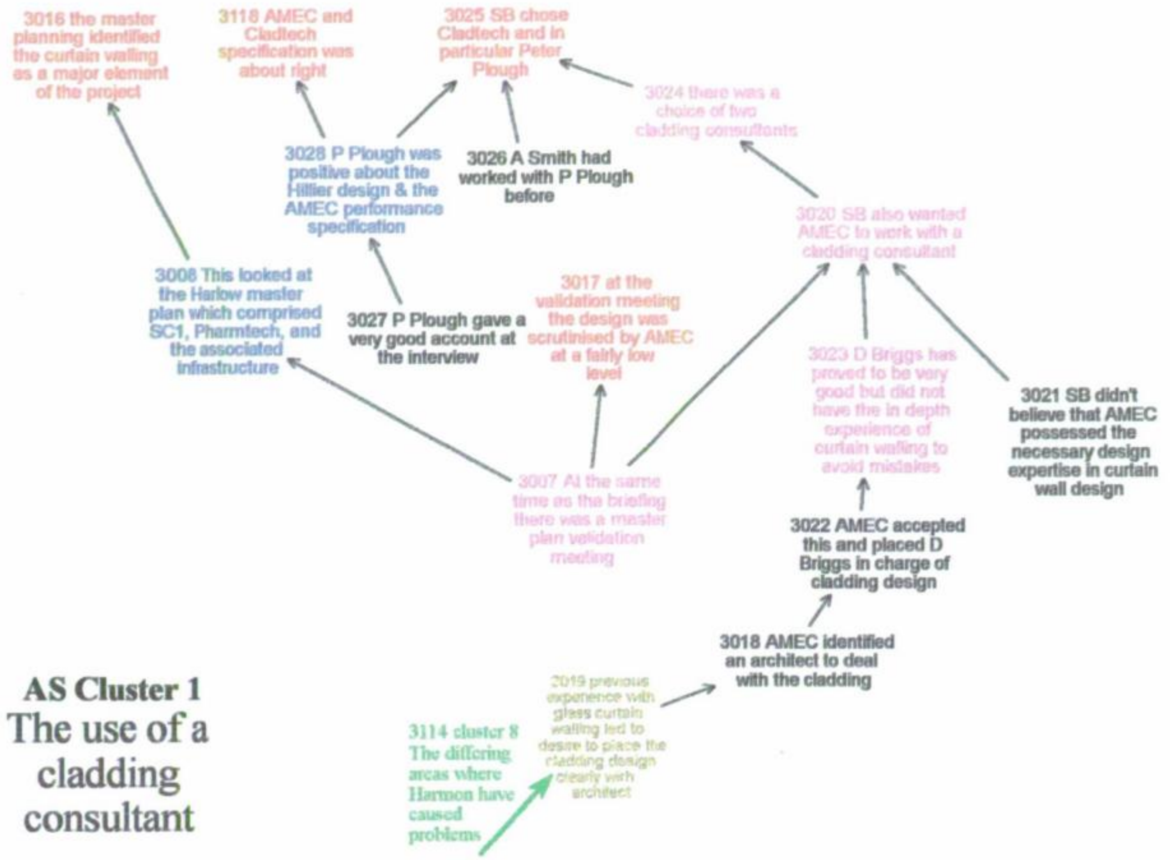
The reasons for Harmons appointment



MW Cluster 9

The problems that have resulted from using Harmon

AS Cluster 1
The use of a cladding consultant

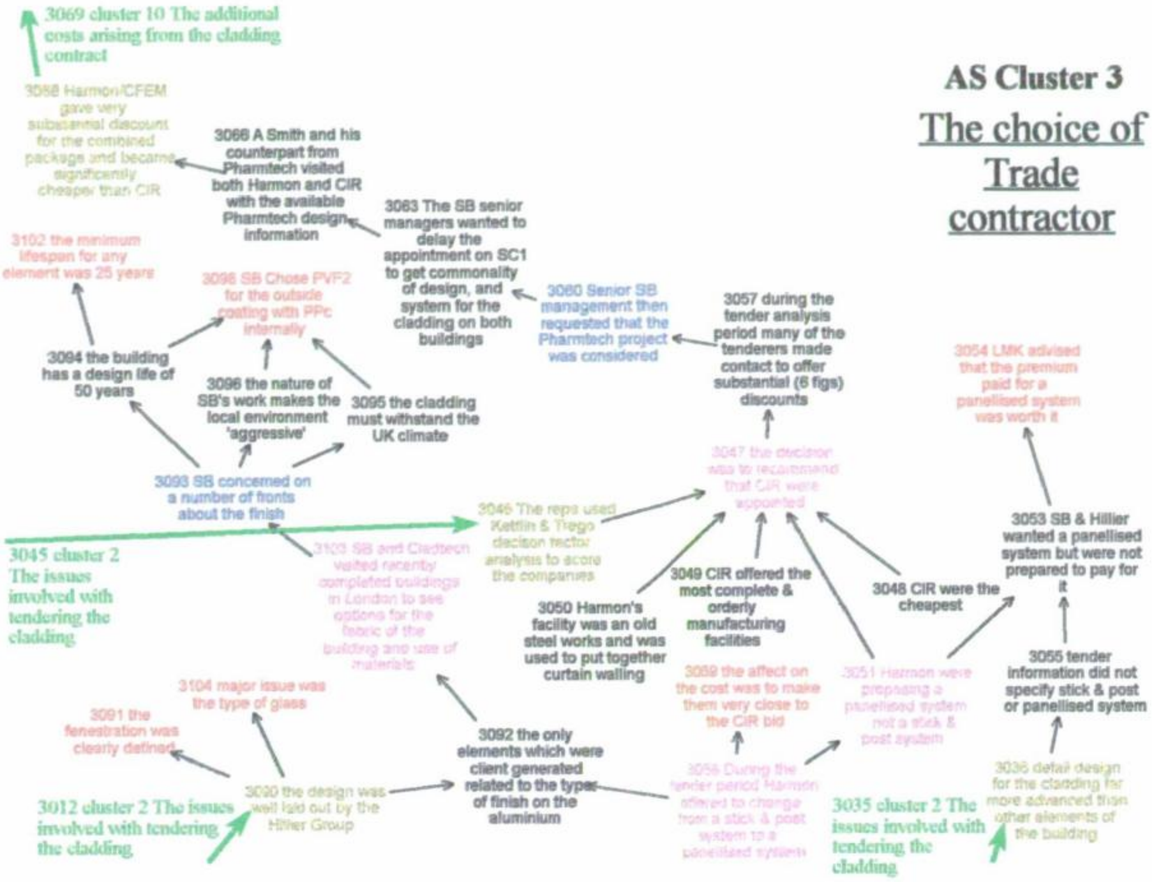


AS Cluster 2

The issues involved with tendering the cladding

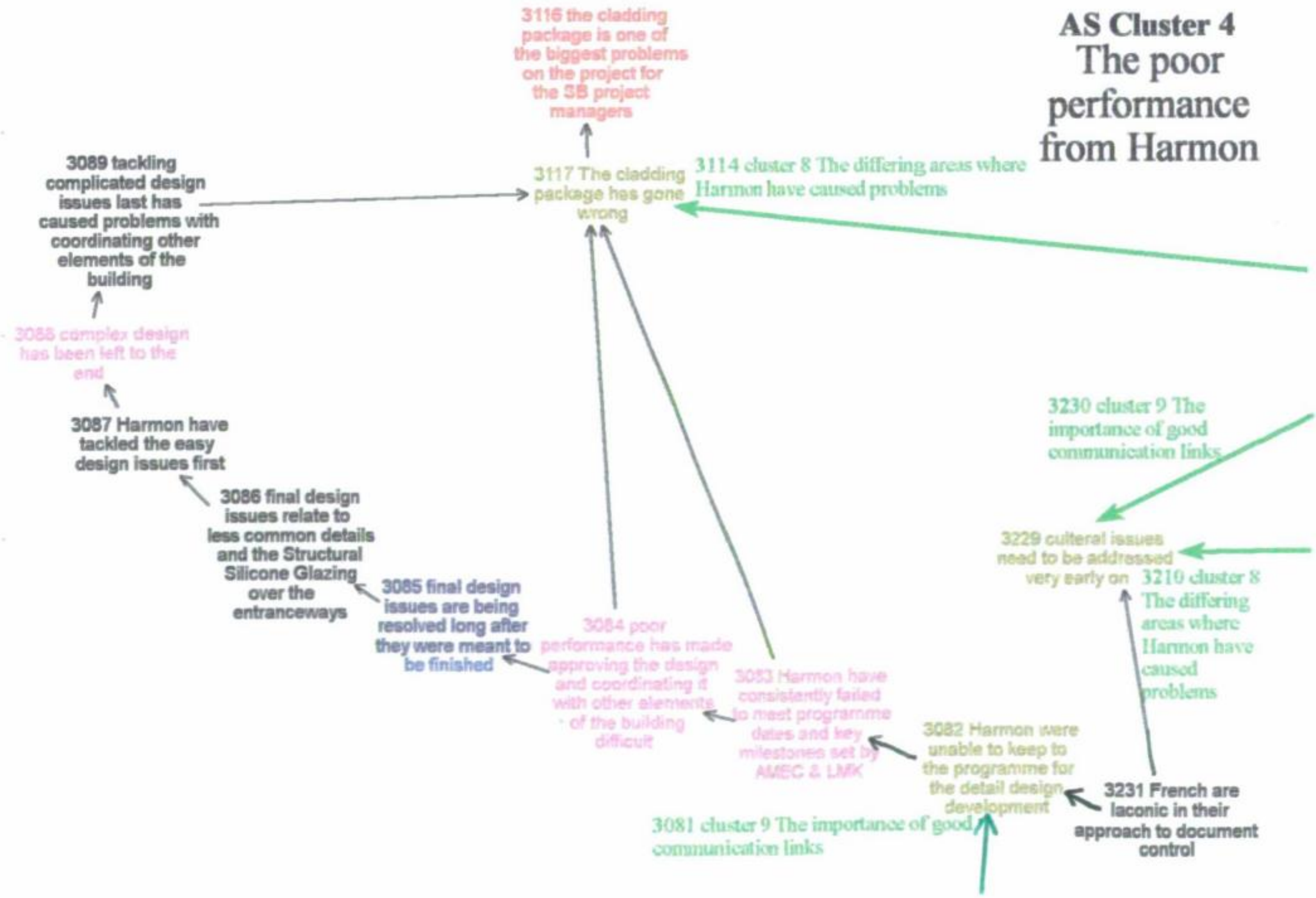
AS Cluster 3

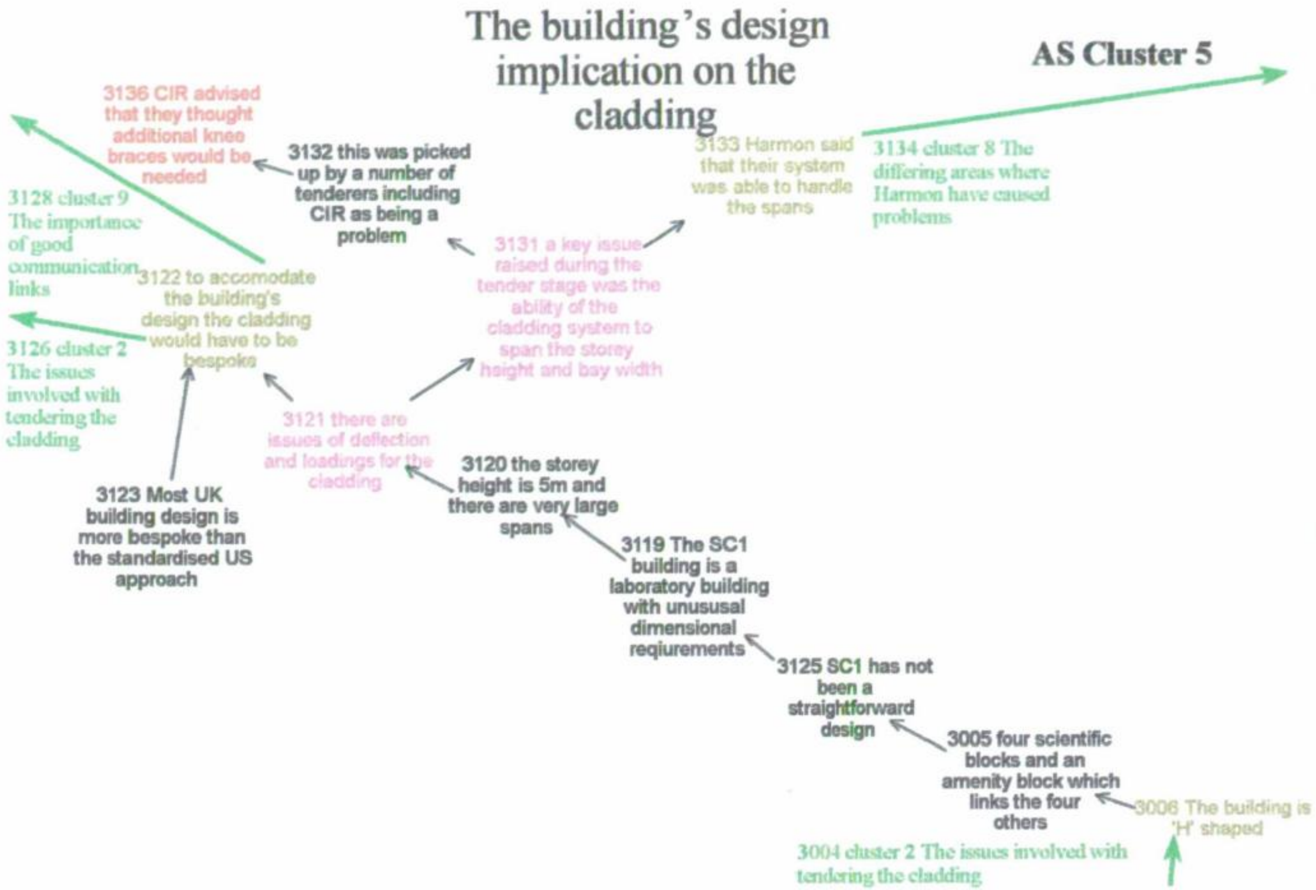
The choice of Trade contractor



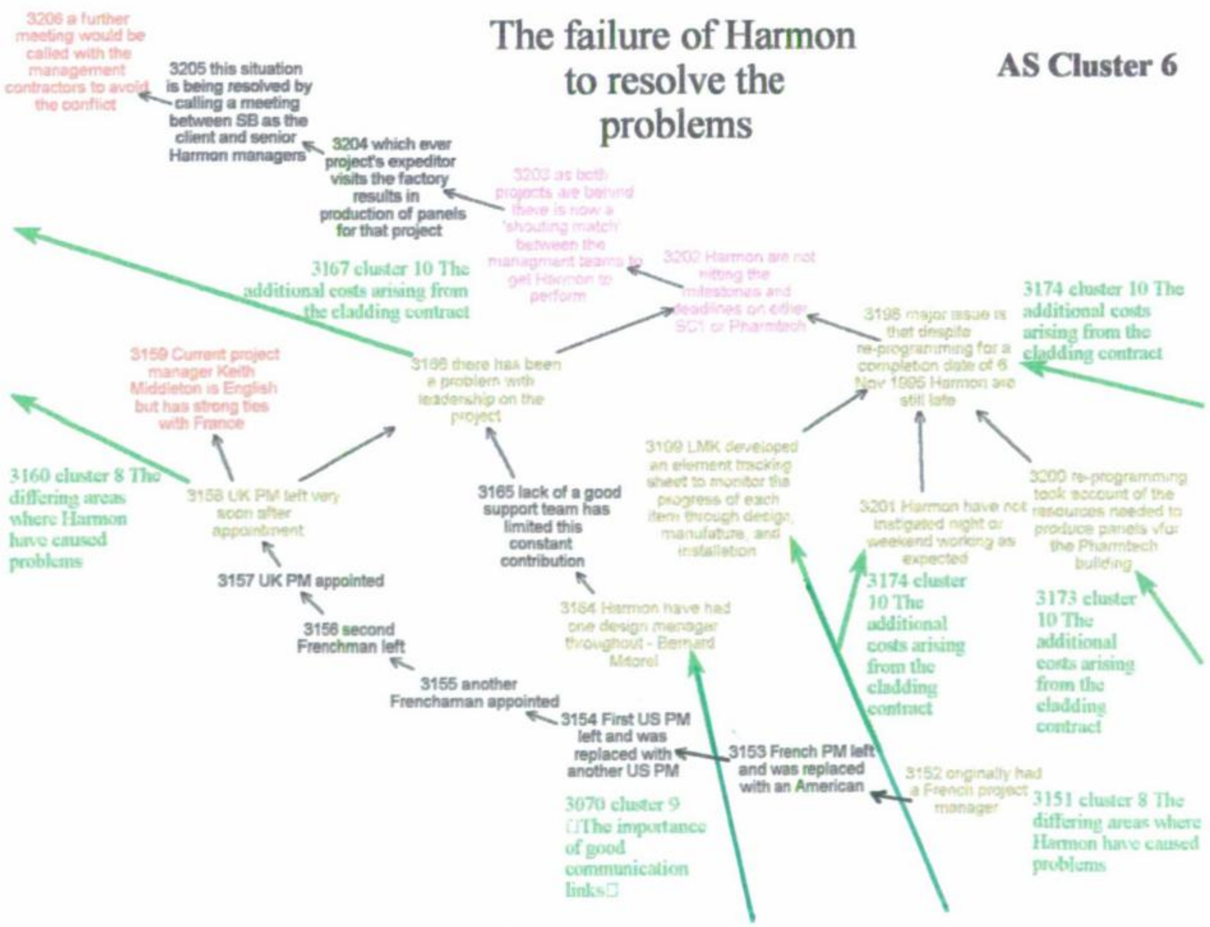
AS Cluster 4

The poor performance from Harmon

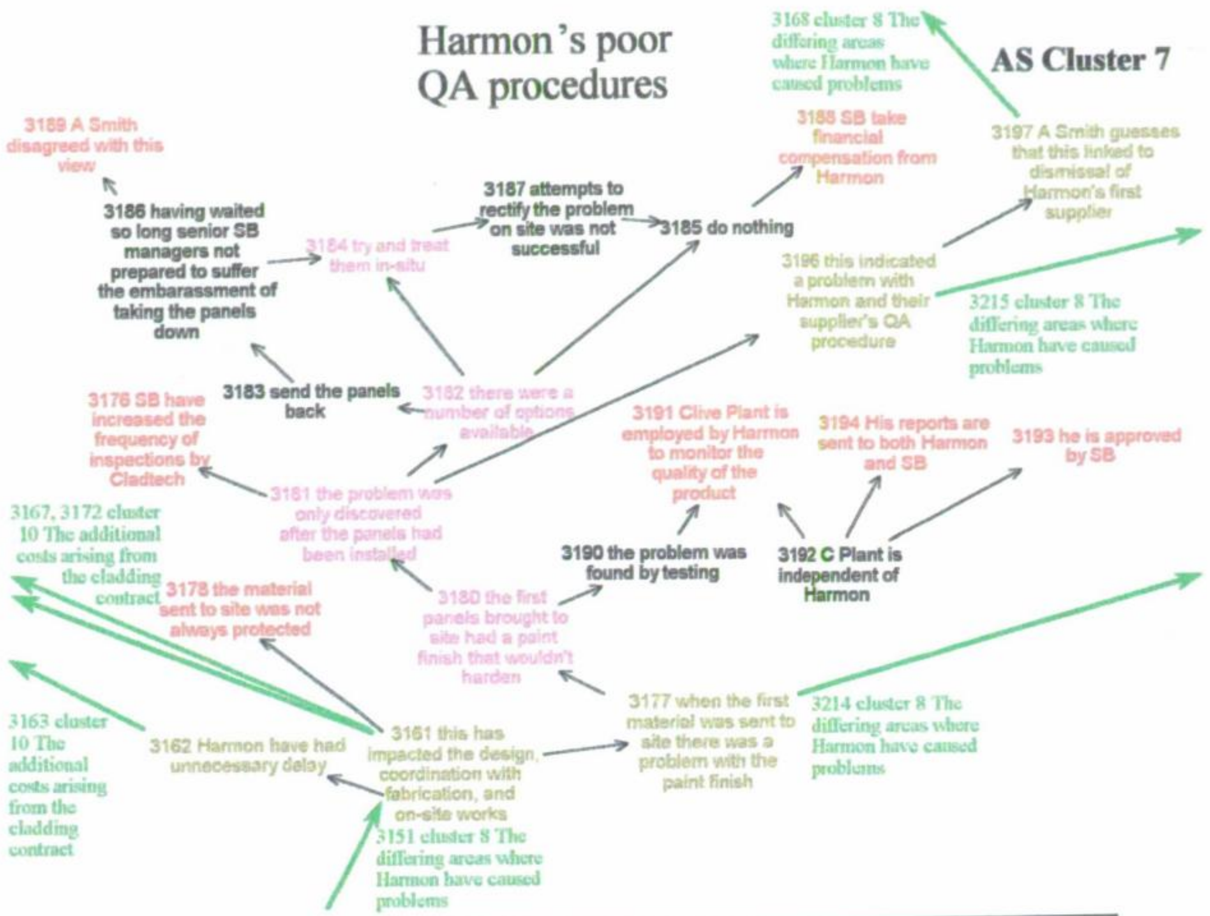




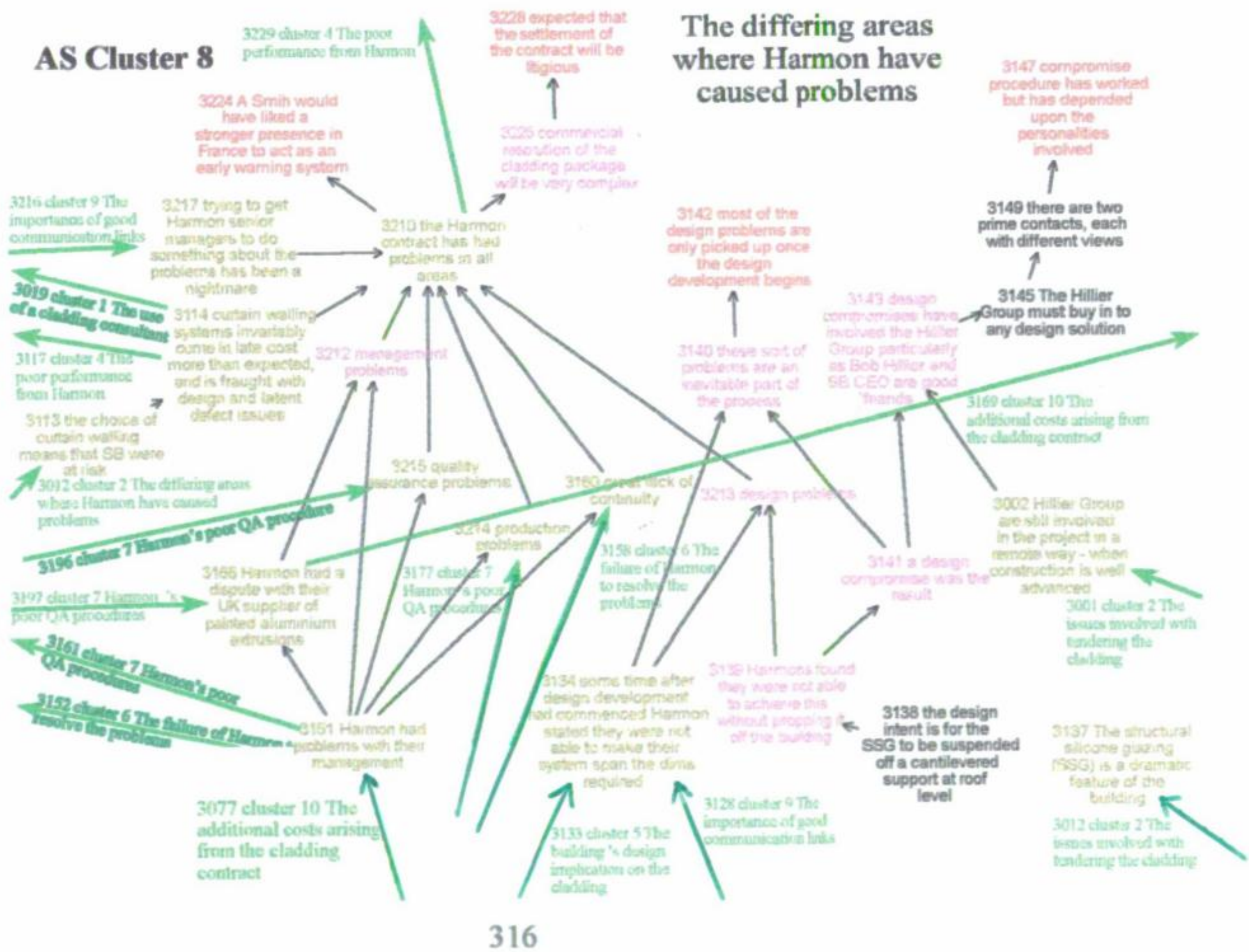
The building's design implication on the cladding
AS Cluster 5
3136 CIR advised that they thought additional knee braces would be needed
3132 this was picked up by a number of tenderers including CIR as being a problem
3133 Harmon said that their system was able to handle the spans
3134 cluster 8 The differing areas where Harmon have caused problems
3128 cluster 9 The importance of good communication links
3122 to accomodate the building's design the cladding would have to be bespoke
3131 a key issue raised during the tender stage was the ability of the cladding system to span the storey height and bay width
3126 cluster 2 The issues involved with tendering the cladding
3121 there are issues of deflection and loadings for the cladding
3120 the storey height is 5m and there are very large spans
3123 Most UK building design is more bespoke than the standardised US approach
3119 The SC1 building is a laboratory building with unusual dimensional reqiurements
3125 SC1 has not been a straightforward design
3005 four scientific blocks and an amenity block which links the four others
3006 The building is 'H' shaped
3004 cluster 2 The issues involved with tendering the cladding



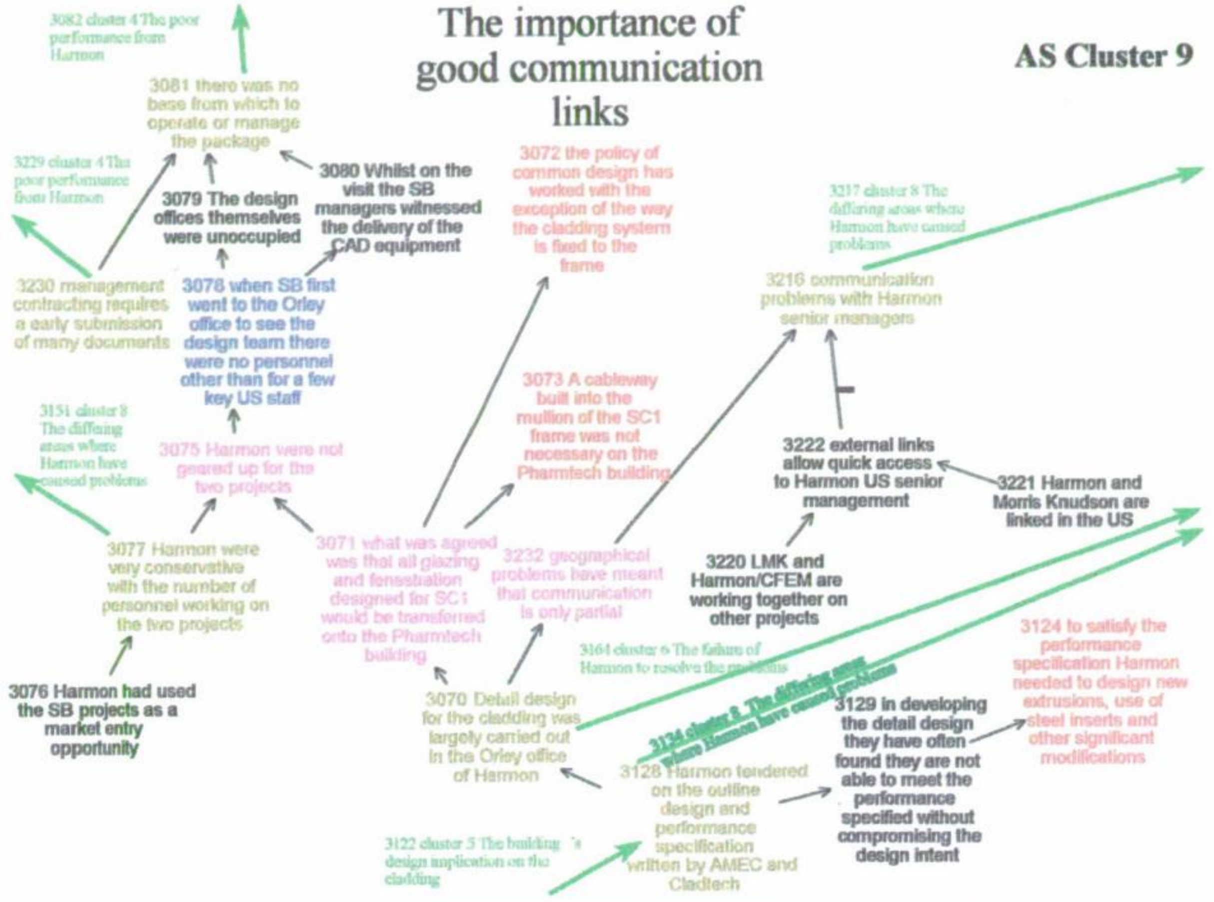
The failure of Harmon to resolve the problems
AS Cluster 6
3206 a further meeting would be called with the management contractors to avoid the conflict
3205 this situation is being resolved by calling a meeting between SB as the client and senior Harmon managers
3204 which ever project's expeditor visits the factory results in production of panels for that project
3203 as both projects are behind there is now a 'shouting match' between the managment teams to get Harmon to perform
3202 Harmon are not hitting the milestones and deadlines on either SC1 or Pharmtech
3167 cluster 10 The additional costs arising from the cladding contract
3174 cluster 10 The additional costs arising from the cladding contract
3198 major issue is that despite re-programming for a completion date of 6 Nov 1995 Harmon are still late
3159 Current project manager Keith Middleton is English but has strong ties with France
3166 there has been a problem with leadership on the project
3199 LMK developed an element tracking sheet to monitor the progress of each item through design, manufature, and installation
3160 cluster 8 The differing areas where Harmon have caused problems
3158 UK PM left very soon after appointment
3165 lack of a good support team has limited this constant contribution
3201 Harmon have not instigated night or weekend working as expected
3200 re-programming took account of the resources needed to produce panels vfor the Pharmtech building
3157 UK PM appointed
3174 cluster 10 The additional costs arising from the cladding contract
3173 cluster 10 The additional costs arising from the cladding contract
3164 Harmon have had one design manager throughout - Bernard Mitorel
3156 second Frenchman left
3155 another Frenchaman appointed
3154 First US PM left and was replaced with another US PM
3153 French PM left and was replaced with an American
3152 originally had a French project manager
3151 cluster 8 The differing areas where Harmon have caused problems
3070 cluster 9 The importance of good communication links



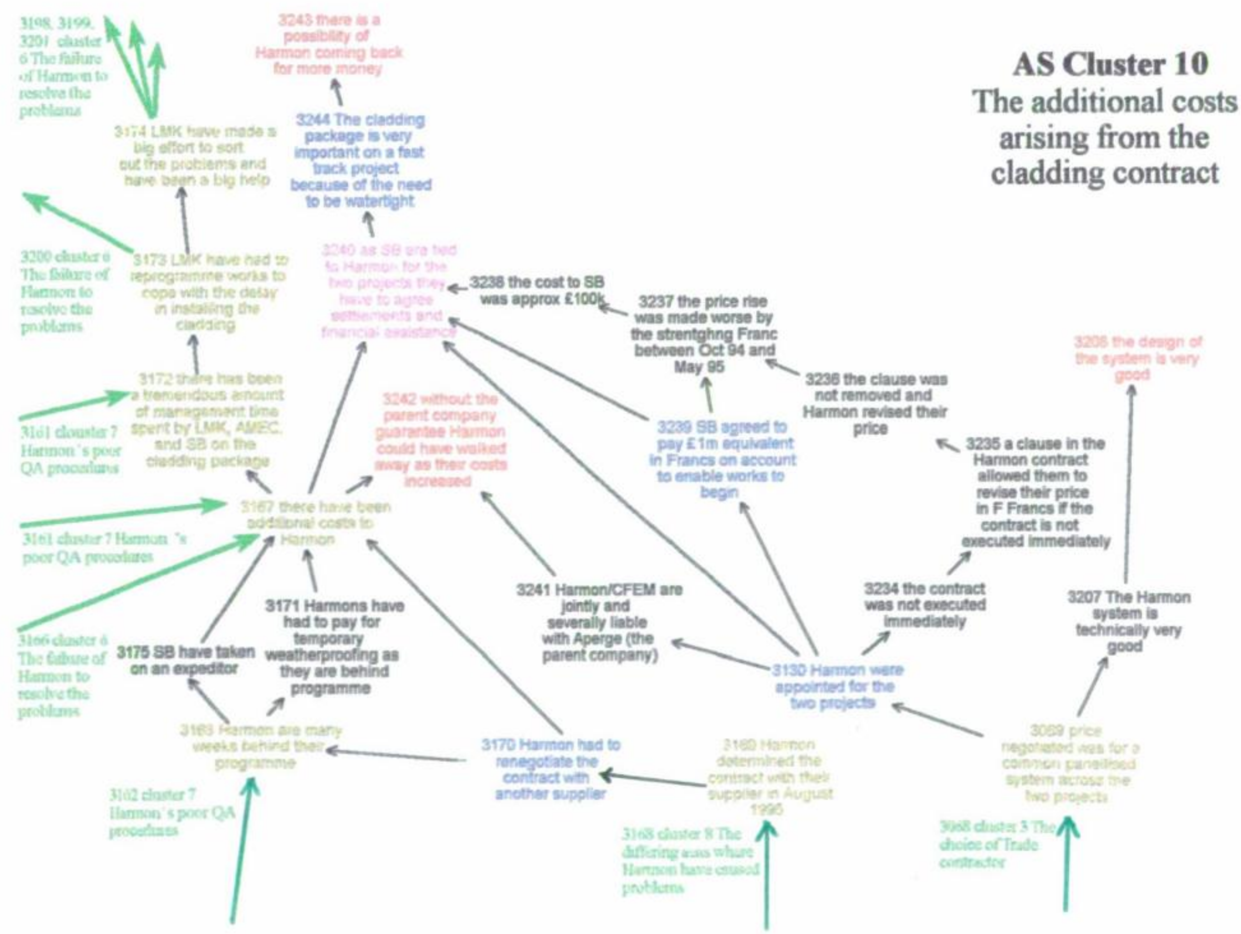
Harmon's poor QA procedures
AS Cluster 7
3168 cluster 8 The differing areas where Harmon have caused problems
3189 A Smith disagreed with this view
3188 SB take financial compensation from Harmon
3197 A Smith guesses that this linked to dismissal of Harmon's first supplier
3186 having waited so long senior SB managers not prepared to suffer the embarassment of taking the panels down
3187 attempts to rectify the problem on site was not successful
3184 try and treat them in-situ
3185 do nothing
3196 this indicated a problem with Harmon and their supplier's QA procedure
3215 cluster 8 The differing areas where Harmon have caused problems
3176 SB have increased the frequency of inspections by Cladtech
3183 send the panels back
3182 there were a number of options available
3191 Clive Plant is employed by Harmon to monitor the quality of the product
3194 His reports are sent to both Harmon and SB
3193 he is approved by SB
3167, 3172 cluster 10 The additional costs arising from the cladding contract
3181 the problem was only discovered after the panels had been installed
3190 the problem was found by testing
3192 C Plant is independent of Harmon
3178 the material sent to site was not always protected
3180 the first panels brought to site had a paint finish that wouldn't harden
3163 cluster 10 The additional costs arising from the cladding contract
3162 Harmon have had unnecessary delay
3161 this has impacted the design, coordination with fabrication, and on-site works
3177 when the first material was sent to site there was a problem with the paint finish
3214 cluster 8 The differing areas where Harmon have caused problems
3151 cluster 8 The differing areas where Harmon have caused problems



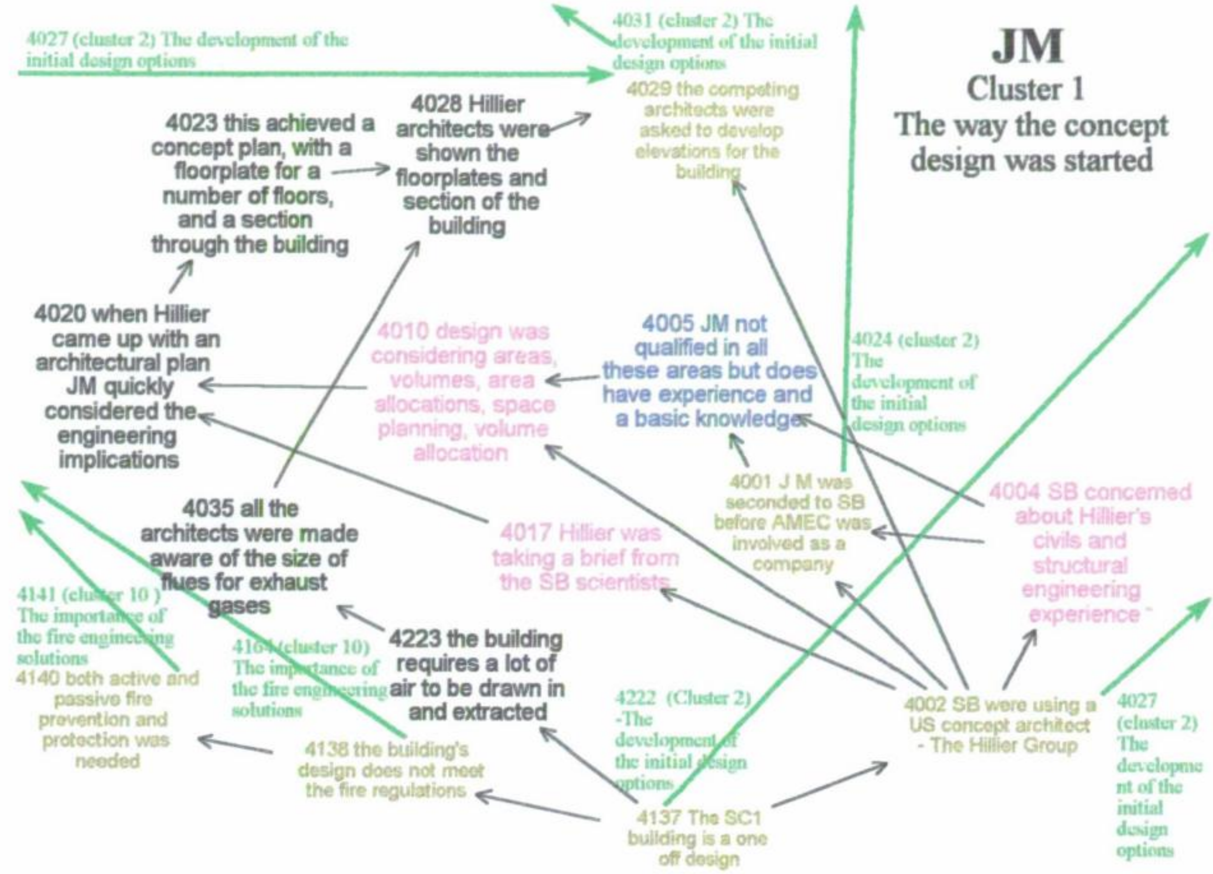
AS Cluster 8
The differing areas where Harmon have caused problems
3229 cluster 4 The poor performance from Harmon
3228 expected that the settlement of the contract will be litigious
3224 A Smih would have liked a stronger presence in France to act as an early warning system
3225 commercial resolution of the cladding package will be very complex
3147 compromise procedure has worked but has depended upon the personalities involved
3216 cluster 9 The importance of good communication links
3217 trying to get Harmon senior managers to do something about the problems has been a nightmare
3210 the Harmon contract has had problems in all areas
3142 most of the design problems are only picked up once the design development begins
3149 there are two prime contacts, each with different views
3019 cluster 1 The use of a cladding consultant
3114 curtain walling systems invariably come in late cost more than expected, and is fraught with design and latent defect issues
3212 management problems
3143 design compromises have involved the Hillier Group particularly as Bob Hillier and SB CEO are good friends
3145 The Hillier Group must buy in to any design solution
3117 cluster 4 The poor performance from Harmon
3140 these sort of problems are an inevitable part of the process
3169 cluster 10 The additional costs arising from the cladding contract
3113 the choice of curtain walling means that SB were at risk
3215 quality assurance problems
3160 overall lack of continuity
3213 design problems
3002 Hillier Group are still involved in the project in a remote way - when construction is well advanced
3012 cluster 2 The differing areas where Harmon have caused problems
3196 cluster 7 Harmon's poor QA procedure
3214 production problems
3158 cluster 6 The failure of Harmon to resolve the problems
3141 a design compromise was the result
3001 cluster 2 The issues involved with tendering the cladding
3197 cluster 7 Harmon's poor QA procedures
3166 Harmon had a dispute with their UK supplier of painted aluminium extrusions
3177 cluster 7 Harmon's poor QA procedures
3161 cluster 7 Harmon's poor QA procedures
3134 some time after design development had commenced Harmon stated they were not able to make their system span the dims required
3139 Harmons found they were not able to achieve this without propping it off the building
3138 the design intent is for the SSG to be suspended off a cantilevered support at roof level
3152 cluster 6 The failure of Harmon to resolve the problems
3151 Harmon had problems with their management
3137 The structural silicone glazing (SSG) is a dramatic feature of the building
3077 cluster 10 The additional costs arising from the cladding contract
3133 cluster 5 The building's design implication on the cladding
3128 cluster 9 The importance of good communication links
3012 cluster 2 The issues involved with tendering the cladding

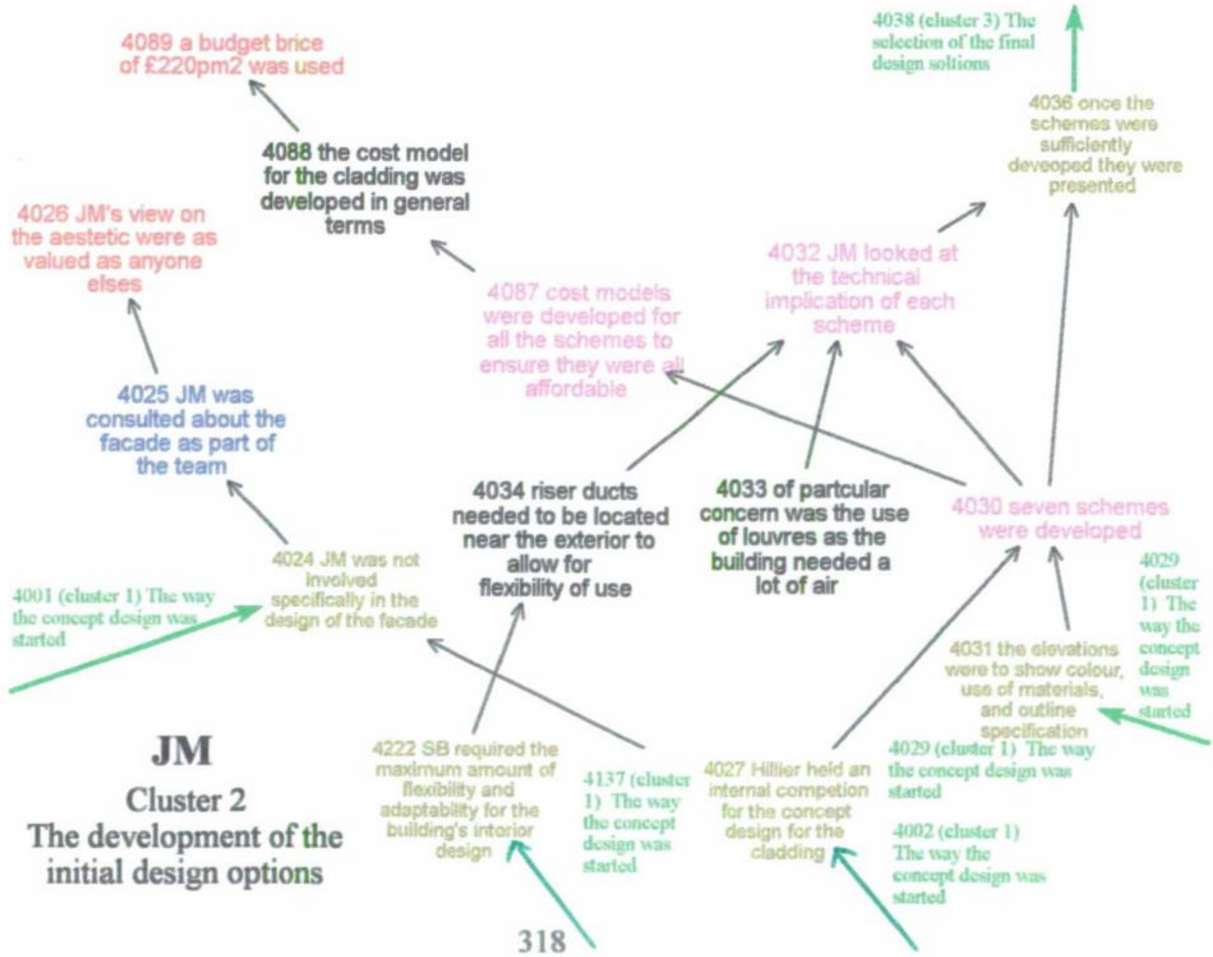


The importance of good communication links
AS Cluster 9
3082 cluster 4 The poor performance from Harmon
3081 there was no base from which to operate or manage the package
3229 cluster 4 The poor performance from Harmon
3079 The design offices themselves were unoccupied
3080 Whilst on the visit the SB managers witnessed the delivery of the CAD equipment
3072 the policy of common design has worked with the exception of the way the cladding system is fixed to the frame
3217 cluster 8 The differing areas where Harmon have caused problems
3216 communication problems with Harmon senior managers
3230 management contracting requires a early submission of many documents
3078 when SB first went to the Orley office to see the design team there were no personnel other than for a few key US staff
3151 cluster 8 The differing areas where Harmon have caused problems
3075 Harmon were not geared up for the two projects
3073 A cableway built into the mullion of the SC1 frame was not necessary on the Pharmtech building
3222 external links allow quick access to Harmon US senior management
3221 Harmon and Morris Knudson are linked in the US
3077 Harmon were very conservative with the number of personnel working on the two projects
3071 what was agreed was that all glazing and fenestration designed for SC1 would be transferred onto the Pharmtech building
3232 geographical problems have meant that communication is only partial
3220 LMK and Harmon/CFEM are working together on other projects
3164 cluster 6 The failure of Harmon to resolve the problems
3124 to satisfy the performance specification Harmon needed to design new extrusions, use of steel inserts and other significant modifications
3076 Harmon had used the SB projects as a market entry opportunity
3070 Detail design for the cladding was largely carried out in the Orley office of Harmon
3134 cluster 8 The differing areas where Harmon have caused problems
3129 in developing the detail design they have often found they are not able to meet the performance specified without compromising the design intent
3128 Harmon tendered on the outline design and performance specification written by AMEC and Cladtech
3122 cluster 5 The building 's design implication on the cladding



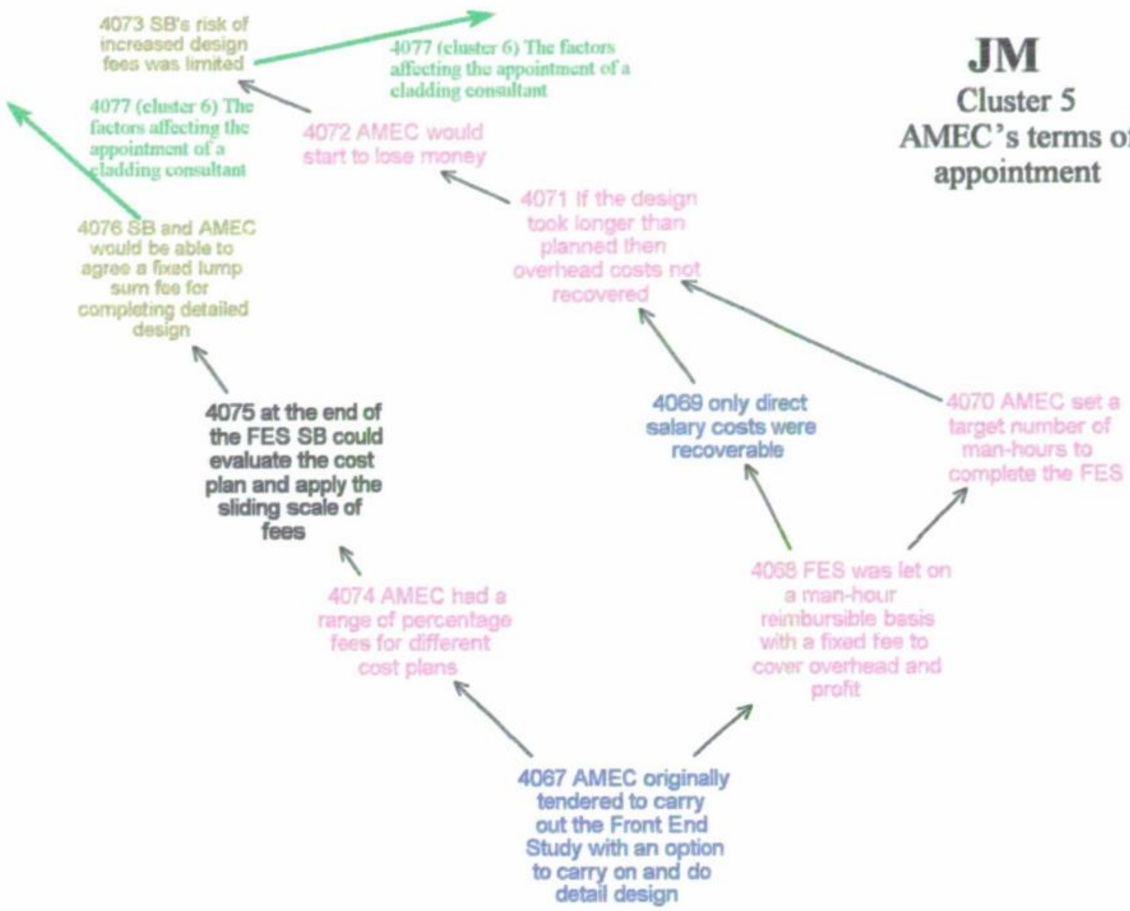
AS Cluster 10
The additional costs arising from the cladding contract
3198, 3199, 3201 cluster 6 The failure of Harmon to resolve the problems
3243 there is a possibility of Harmon coming back for more money
3174 LMK have made a big effort to sort out the problems and have been a big help
3244 The cladding package is very important on a fast track project because of the need to be watertight
3200 cluster 6 The failure of Harmon to resolve the problems
3173 LMK have had to reprogramme works to cope with the delay in installing the cladding
3240 as SB are tied to Harmon for the two projects they have to agree settlements and financial assistance
3238 the cost to SB was approx £100k
3237 the price rise was made worse by the strentghng Franc between Oct 94 and May 95
3206 the design of the system is very good
3236 the clause was not removed and Harmon revised their price
3172 there has been a tremendous amount of management time spent by LMK, AMEC, and SB on the cladding package
3161 clouster 7 Harmon 's poor QA procedures
3242 without the parent company guarantee Harmon could have walked away as their costs increased
3239 SB agreed to pay £1m equivalent in Francs on account to enable works to begin
3235 a clause in the Harmon contract allowed them to revise their price in F Francs if the contract is not executed immediately
3167 there have been additional costs to Harmon
3161 cluster 7 Harmon 's poor QA procedures
3171 Harmons have had to pay for temporary weatherproofing as they are behind programme
3241 Harmon/CFEM are jointly and severally liable with Aperge (the parent company)
3234 the contract was not executed immediately
3207 The Harmon system is technically very good
3166 cluster 6 The failure of Harmon to resolve the problems
3175 SB have taken on an expeditor
3130 Harmon were appointed for the two projects
3169 Harmon are many weeks behind their programme
3170 Harmon had to renegotiate the contract with another supplier
3169 Harmon determined the contract with their supplier in August 1995
3069 price negotiated was for a common panellised system across the two projects
3102 cluster 7 Harmon 's poor QA procedures
3168 cluster 8 The differing areas where Harmon have caused problems
3068 cluster 3 The choice of Trade contractor


JM
Cluster 1
The way the concept design was started
4027 (cluster 2) The development of the initial design options
4031 (cluster 2) The development of the initial design options
4029 the competing architects were asked to develop elevations for the building
4028 Hillier architects were shown the floorplates and section of the building
4023 this achieved a concept plan, with a floorplate for a number of floors, and a section through the building
4020 when Hillier came up with an architectural plan JM quickly considered the engineering implications
4010 design was considering areas, volumes, area allocations, space planning, volume allocation
4005 JM not qualified in all these areas but does have experience and a basic knowledge
4024 (cluster 2) The development of the initial design options
4001 J M was seconded to SB before AMEC was involved as a company
4004 SB concerned about Hillier's civils and structural engineering experience
4035 all the architects were made aware of the size of flues for exhaust gases
4017 Hillier was taking a brief from the SB scientists
4141 (cluster 10) The importance of the fire engineering solutions
4140 both active and passive fire prevention and protection was needed
4164 (cluster 10) The importance of the fire engineering solutions
4223 the building requires a lot of air to be drawn in and extracted
4222 (Cluster 2) -The development of the initial design options
4002 SB were using a US concept architect - The Hillier Group
4027 (cluster 2) The development of the initial design options
4138 the building's design does not meet the fire regulations
4137 The SC1 building is a one off design

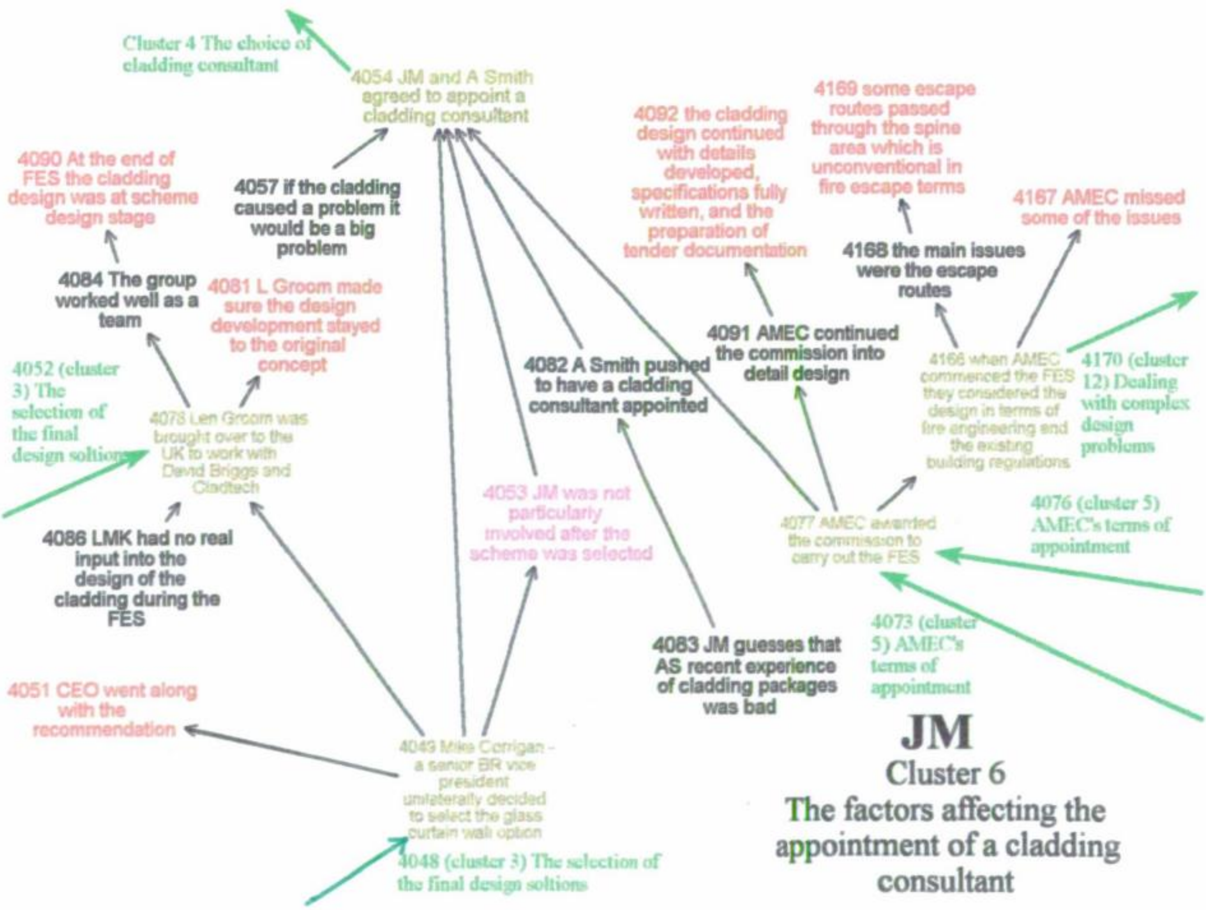

4038 (cluster 3) The selection of the final design soltions
4089 a budget brice of £220pm2 was used
4088 the cost model for the cladding was developed in general terms
4036 once the schemes were sufficiently deveoped they were presented
4026 JM's view on the aestetic were as valued as anyone elses
4032 JM looked at the technical implication of each scheme
4087 cost models were developed for all the schemes to ensure they were all affordable
4025 JM was consulted about the facade as part of the team
4034 riser ducts needed to be located near the exterior to allow for flexibility of use
4033 of partcular concern was the use of louvres as the building needed a lot of air
4030 seven schemes were developed
4024 JM was not involved specifically in the design of the facade
4001 (cluster 1) The way the concept design was started
4029 (cluster 1) The way the concept design was started
4031 the elevations were to show colour, use of materials, and outline specification
4029 (cluster 1) The way the concept design was started
JM
Cluster 2
The development of the initial design options
4222 SB required the maximum amount of flexibility and adaptability for the building's interior design
4137 (cluster 1) The way the concept design was started
4027 Hillier held an internal competion for the concept design for the cladding
4002 (cluster 1) The way the concept design was started

JM
Cluster 3
The selection of the final design solutions

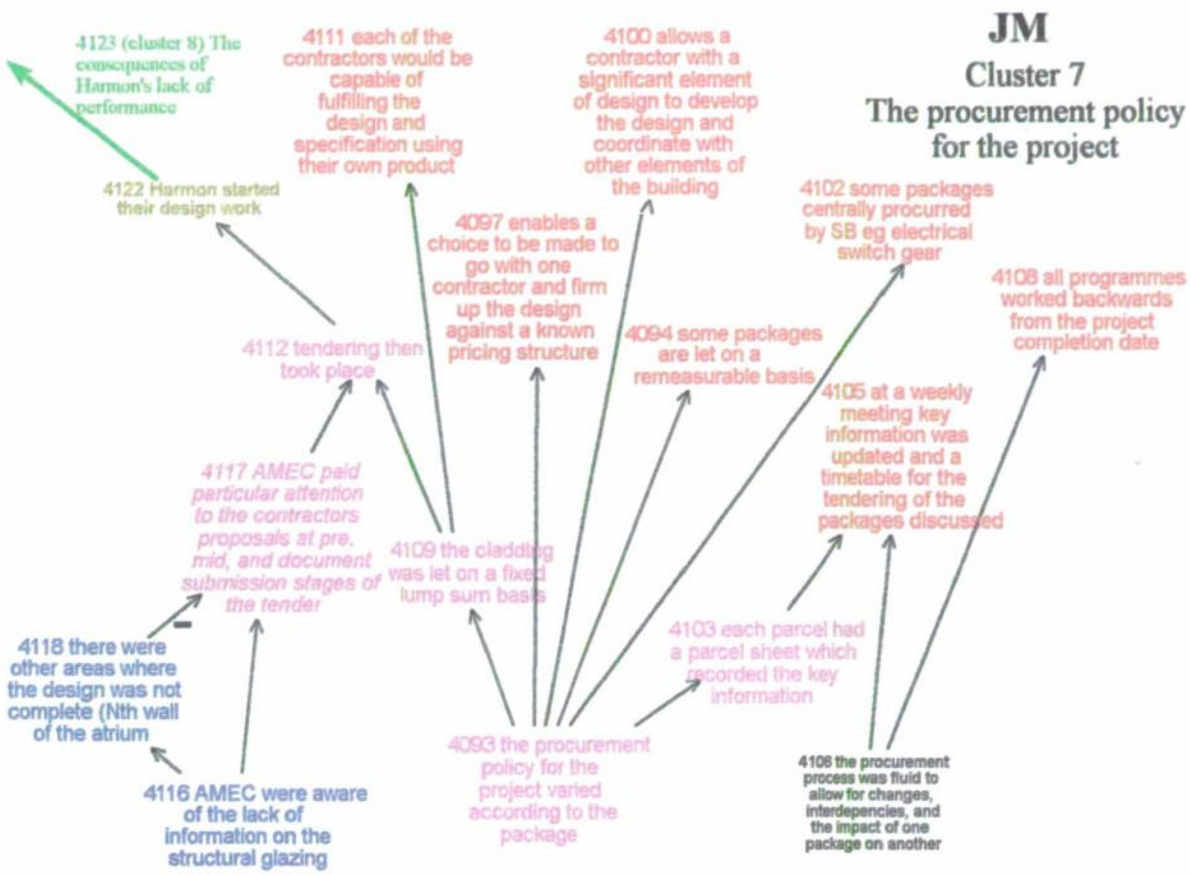
JM
Cluster 4
The choice of cladding consultant

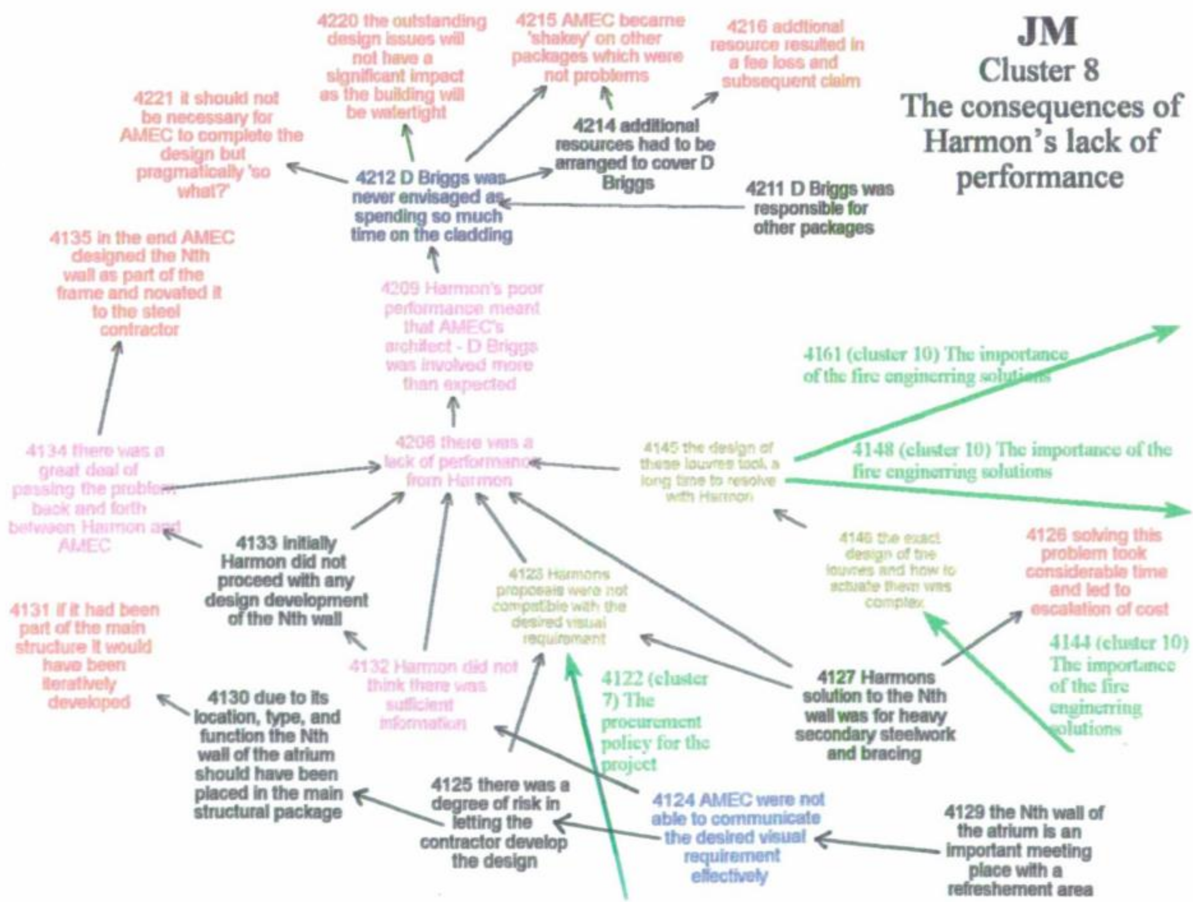


JM
Cluster 5
AMEC's terms of appointment

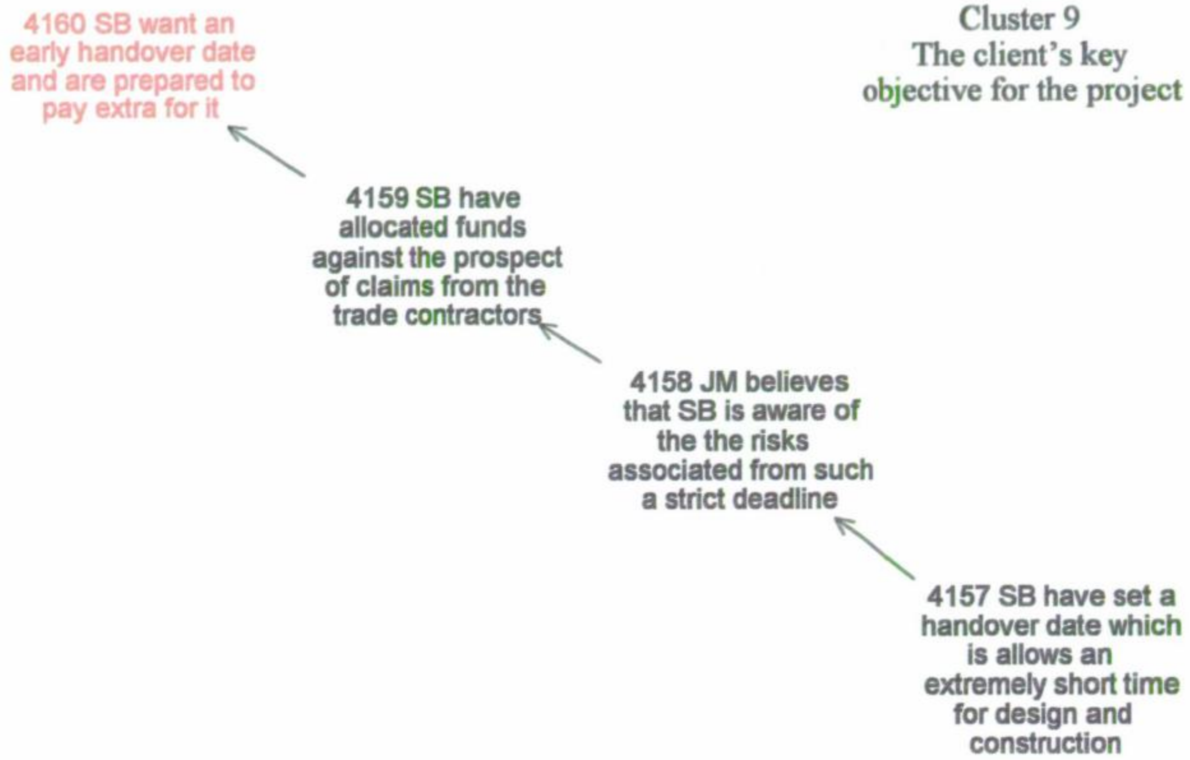


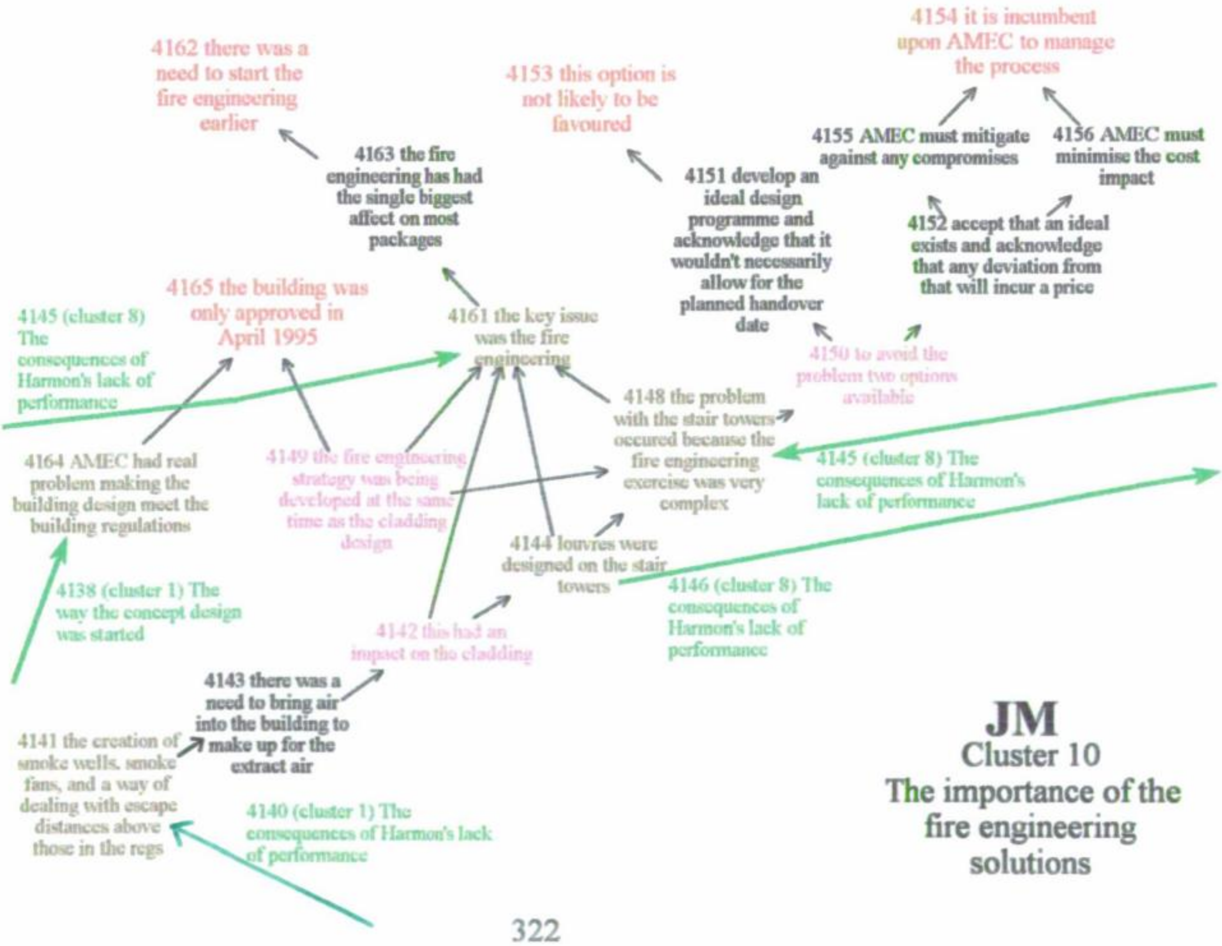
JM
Cluster 6
The factors affecting the appointment of a cladding consultant


JM
Cluster 7
The procurement policy for the project
4123 (cluster 8) The consequences of Harmon's lack of performance
4111 each of the contractors would be capable of fulfilling the design and specification using their own product
4100 allows a contractor with a significant element of design to develop the design and coordinate with other elements of the building
4122 Harmon started their design work
4102 some packages centrally procurred by SB eg electrical switch gear
4097 enables a choice to be made to go with one contractor and firm up the design against a known pricing structure
4108 all programmes worked backwards from the project completion date
4112 tendering then took place
4094 some packages are let on a remeasurable basis
4105 at a weekly meeting key information was updated and a timetable for the tendering of the packages discussed
4117 AMEC paid particular attention to the contractors proposals at pre, mid, and document submission stages of the tender
4109 the cladding was let on a fixed lump sum basis
4118 there were other areas where the design was not complete (Nth wall of the atrium
4103 each parcel had a parcel sheet which recorded the key information
4093 the procurement policy for the project varied according to the package
4106 the procurement process was fluid to allow for changes, interdepencies, and the impact of one package on another
4116 AMEC were aware of the lack of information on the structural glazing

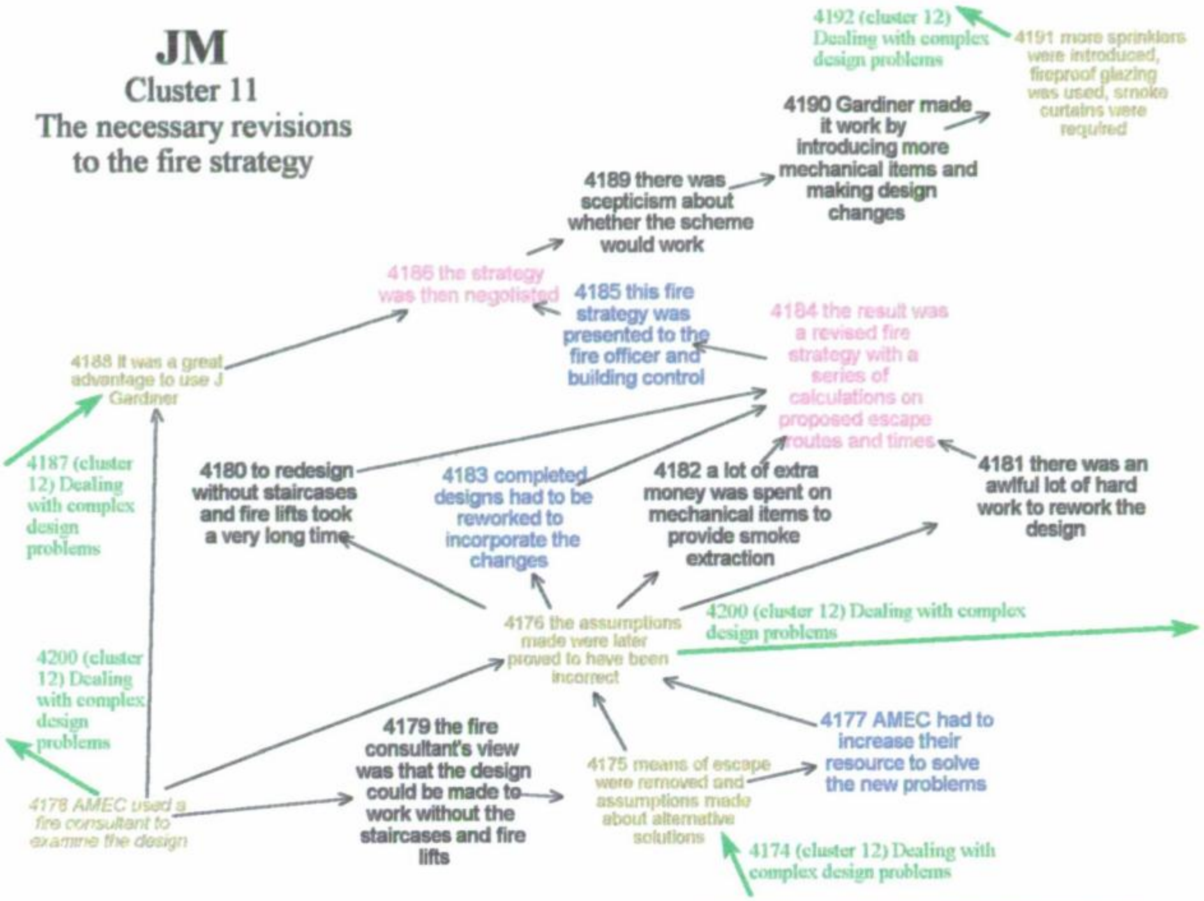

JM
Cluster 8
The consequences of Harmon's lack of performance
4220 the outstanding design issues will not have a significant impact as the building will be watertight
4215 AMEC became 'shakey' on other packages which were not problems
4216 addtional resource resulted in a fee loss and subsequent claim
4221 it should not be necessary for AMEC to complete the design but pragmatically 'so what?'
4214 additional resources had to be arranged to cover D Briggs
4212 D Briggs was never envisaged as spending so much time on the cladding
4211 D Briggs was responsible for other packages
4135 in the end AMEC designed the Nth wall as part of the frame and novated it to the steel contractor
4209 Harmon's poor performance meant that AMEC's architect - D Briggs was involved more than expected
4161 (cluster 10) The importance of the fire engineerring solutions
4134 there was a great deal of passing the problem back and forth between Harmon and AMEC
4208 there was a lack of performance from Harmon
4145 the design of these louvres tool, a long time to resolve with Harmon
4148 (cluster 10) The importance of the fire engineerring solutions
4133 initially Harmon did not proceed with any design development of the Nth wall
4123 Harmons proposals were not compatible with the desired visual requirement
4146 the exact design of the louvres and how to actuate them was complex
4126 solving this problem took considerable time and led to escalation of cost
4131 if it had been part of the main structure it would have been iteratively developed
4132 Harmon did not think there was sufficient information
4122 (cluster 7) The procurement policy for the project
4144 (cluster 10) The importance of the fire engineerring solutions
4127 Harmons solution to the Nth wall was for heavy secondary steelwork and bracing
4130 due to its location, type, and function the Nth wall of the atrium should have been placed in the main structural package
4125 there was a degree of risk in letting the contractor develop the design
4124 AMEC were not able to communicate the desired visual requirement effectively
4129 the Nth wall of the atrium is an important meeting place with a refreshement area

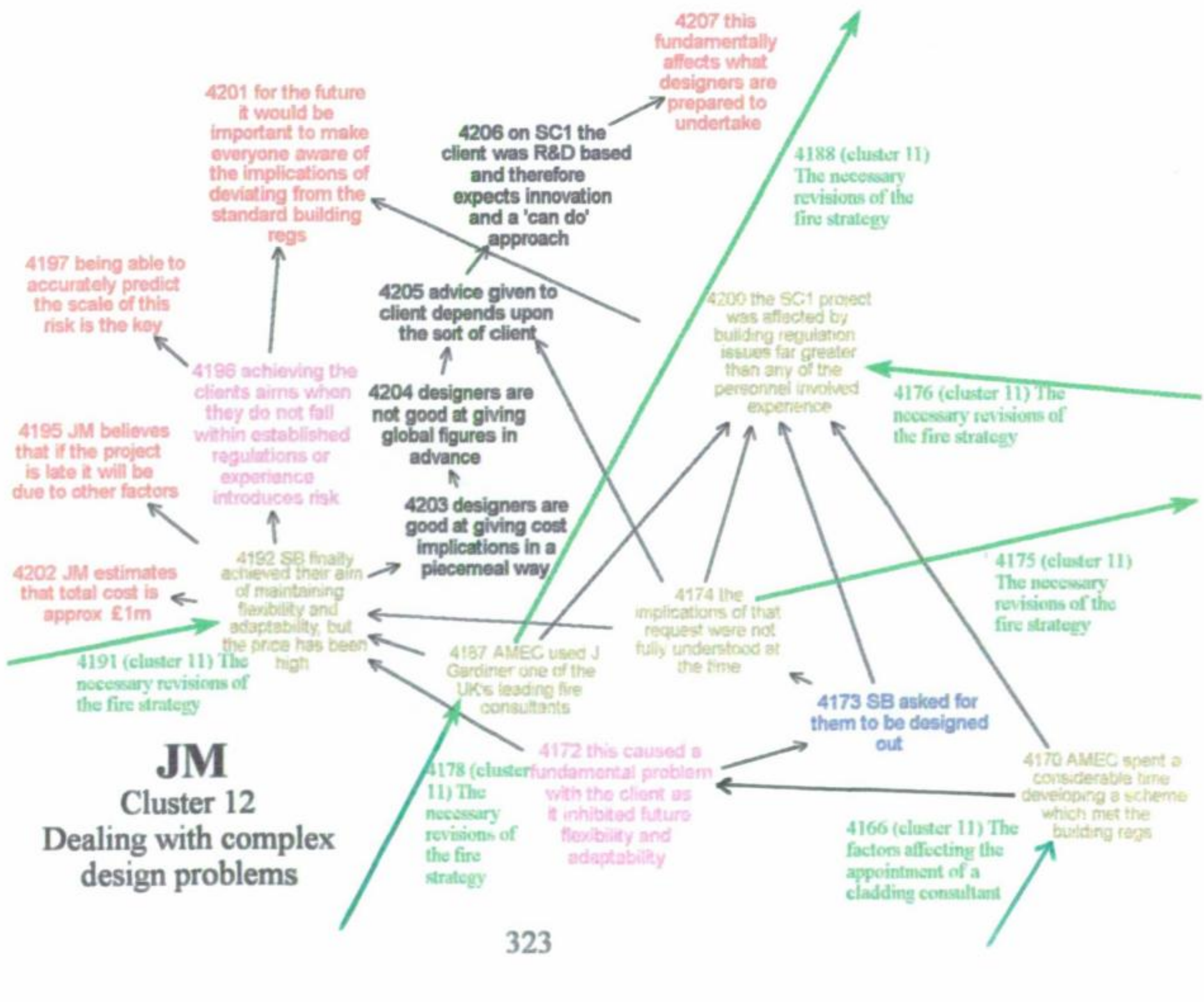
JM
Cluster 9
The client's key objective for the project





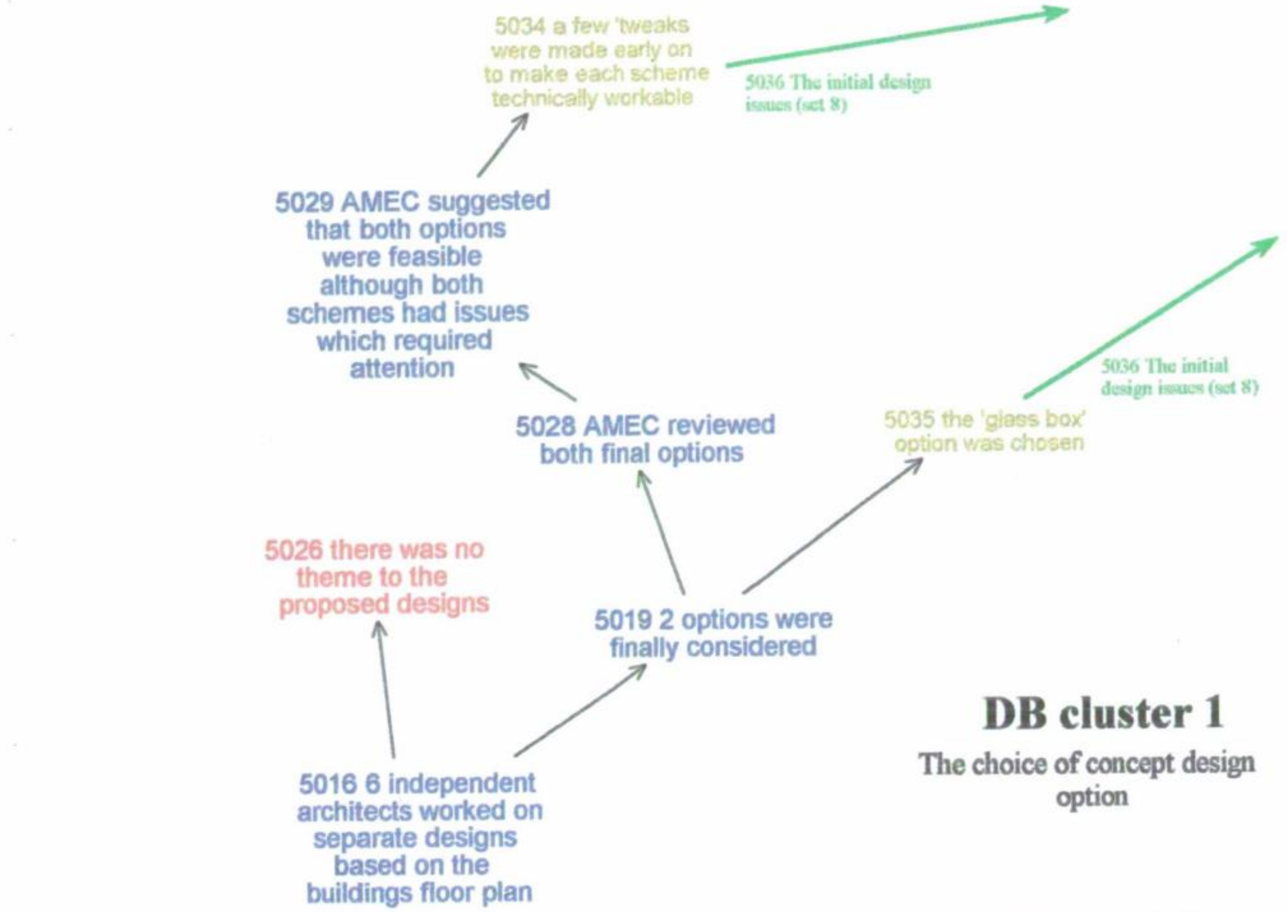
JM
Cluster 10
The importance of the fire engineering solutions


JM
Cluster 11
The necessary revisions to the fire strategy
4192 (cluster 12) Dealing with complex design problems
4191 more sprinklers were introduced, fireproof glazing was used, smoke curtains were required
4190 Gardiner made it work by introducing more mechanical items and making design changes
4189 there was scepticism about whether the scheme would work
4186 the strategy was then negotiated
4185 this fire strategy was presented to the fire officer and building control
4184 the result was a revised fire strategy with a series of calculations on proposed escape routes and times
4188 It was a great advantage to use J Gardiner
4187 (cluster 12) Dealing with complex design problems
4180 to redesign without staircases and fire lifts took a very long time
4183 completed designs had to be reworked to incorporate the changes
4182 a lot of extra money was spent on mechanical items to provide smoke extraction
4181 there was an awful lot of hard work to rework the design
4176 the assumptions made were later proved to have been incorrect
4200 (cluster 12) Dealing with complex design problems
4200 (cluster 12) Dealing with complex design problems
4177 AMEC had to increase their resource to solve the new problems
4179 the fire consultant's view was that the design could be made to work without the staircases and fire lifts
4175 means of escape were removed and assumptions made about alternative solutions
4178 AMEC used a fire consultant to examine the design
4174 (cluster 12) Dealing with complex design problems


4207 this fundamentally affects what designers are prepared to undertake
4201 for the future it would be important to make everyone aware of the implications of deviating from the standard building regs
4206 on SC1 the client was R&D based and therefore expects innovation and a 'can do' approach
4188 (cluster 11) The necessary revisions of the fire strategy
4197 being able to accurately predict the scale of this risk is the key
4205 advice given to client depends upon the sort of client
4200 the SC1 project was affected by building regulation issues far greater than any of the personnel involved experience
4196 achieving the clients aims when they do not fall within established regulations or experience introduces risk
4204 designers are not good at giving global figures in advance
4176 (cluster 11) The necessary revisions of the fire strategy
4195 JM believes that if the project is late it will be due to other factors
4203 designers are good at giving cost implications in a piecemeal way
4202 JM estimates that total cost is approx £1m
4192 SB finally achieved their aim of maintaining flexibility and adaptability, but the price has been high
4174 the implications of that request were not fully understood at the time
4175 (cluster 11) The necessary revisions of the fire strategy
4191 (cluster 11) The necessary revisions of the fire strategy
4187 AMEC used J Gardiner one of the UK's leading fire consultants
4173 SB asked for them to be designed out
4172 this caused a fundamental problem with the client as it inhibited future flexibility and adaptability
4178 (cluster 11) The necessary revisions of the fire strategy
4170 AMEC spent a considerable time developing a scheme which met the building regs
4166 (cluster 11) The factors affecting the appointment of a cladding consultant
JM
Cluster 12
Dealing with complex design problems

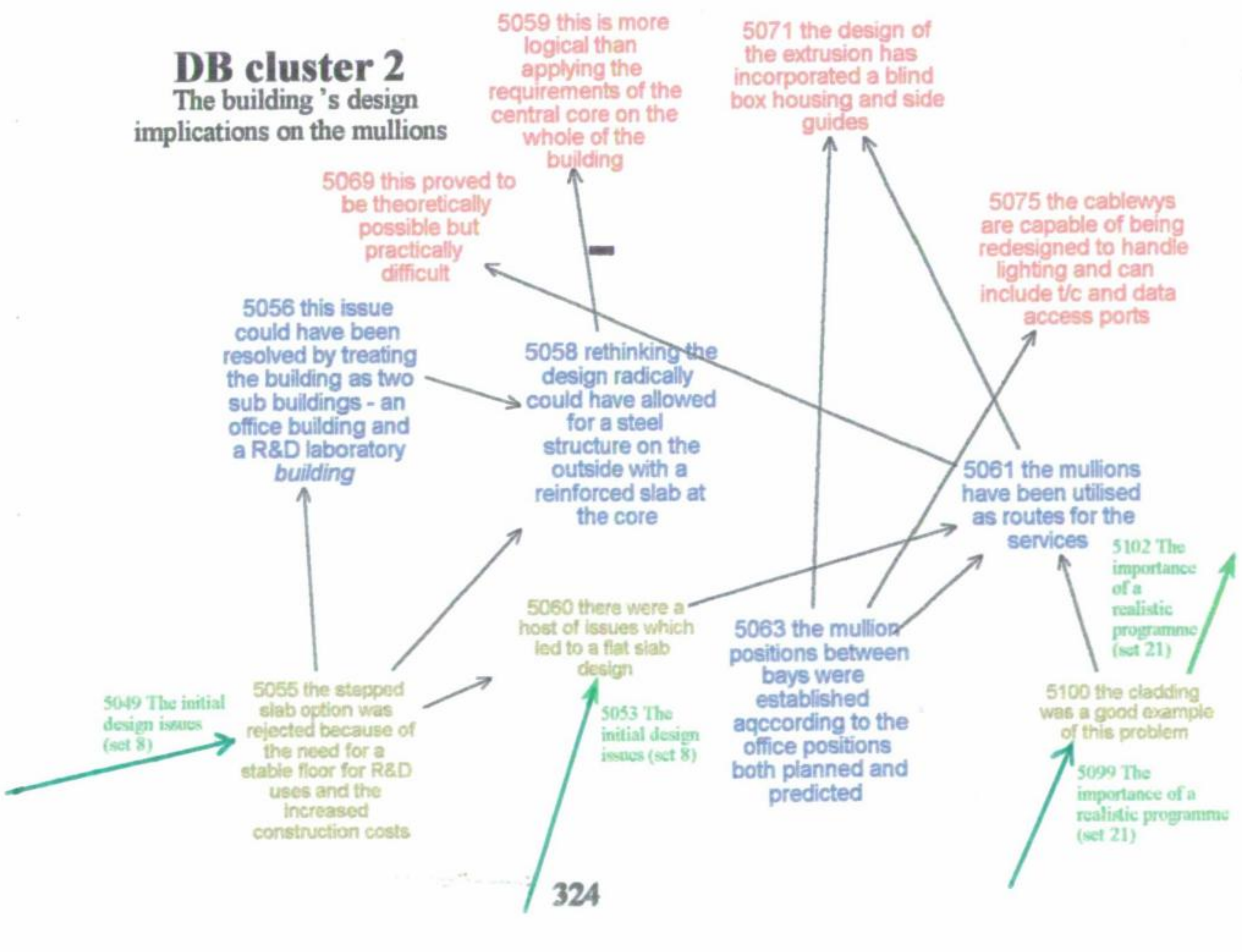
DB cluster 1

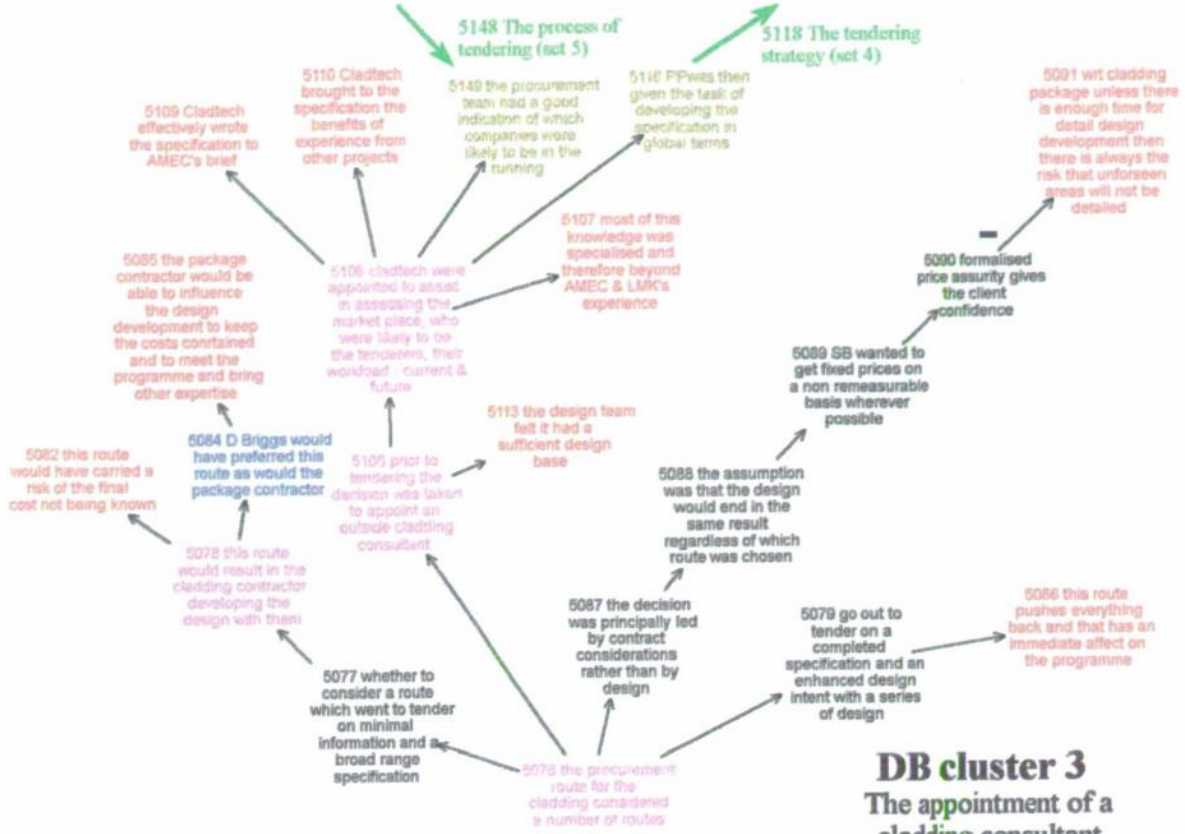
The choice of concept design option



DB cluster 2

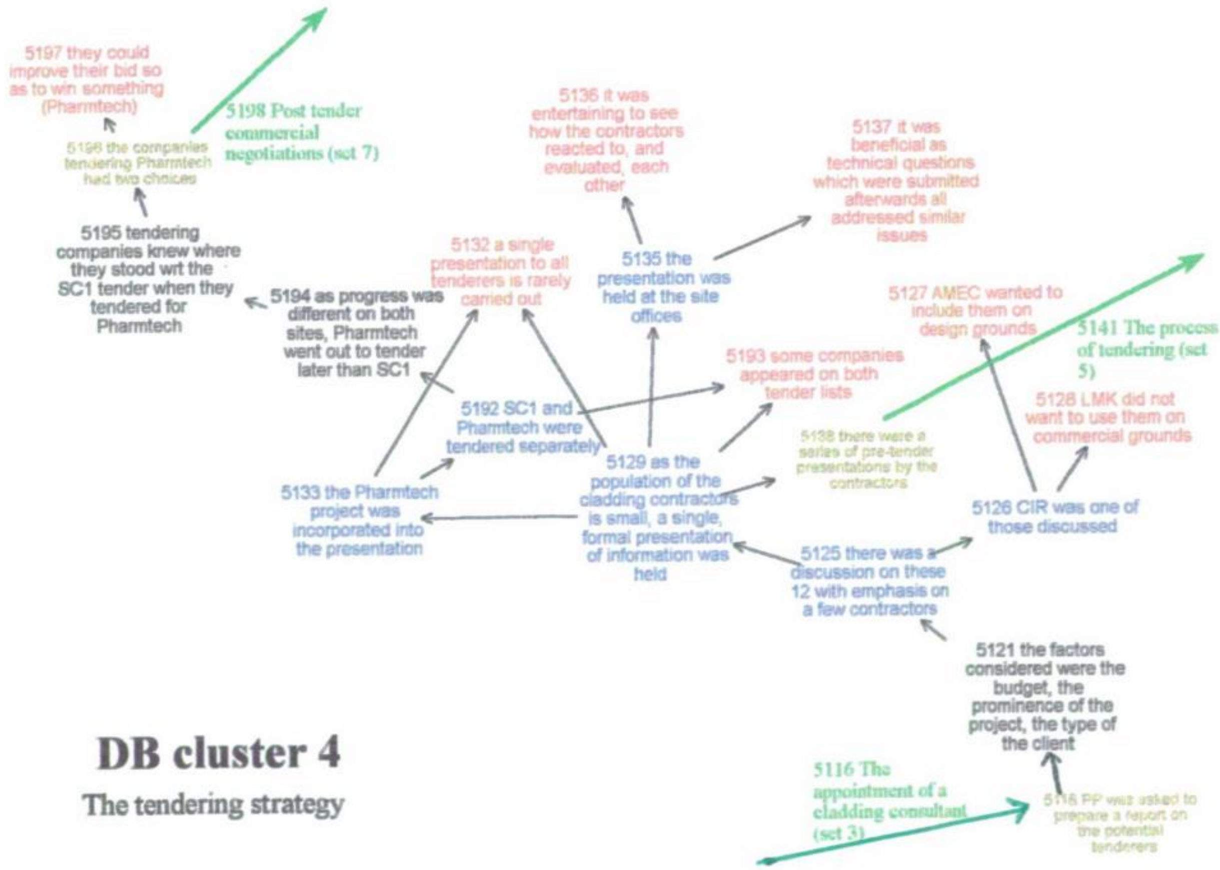
The building 's design implications on the mullions





DB cluster 3

The appointment of a cladding consultant

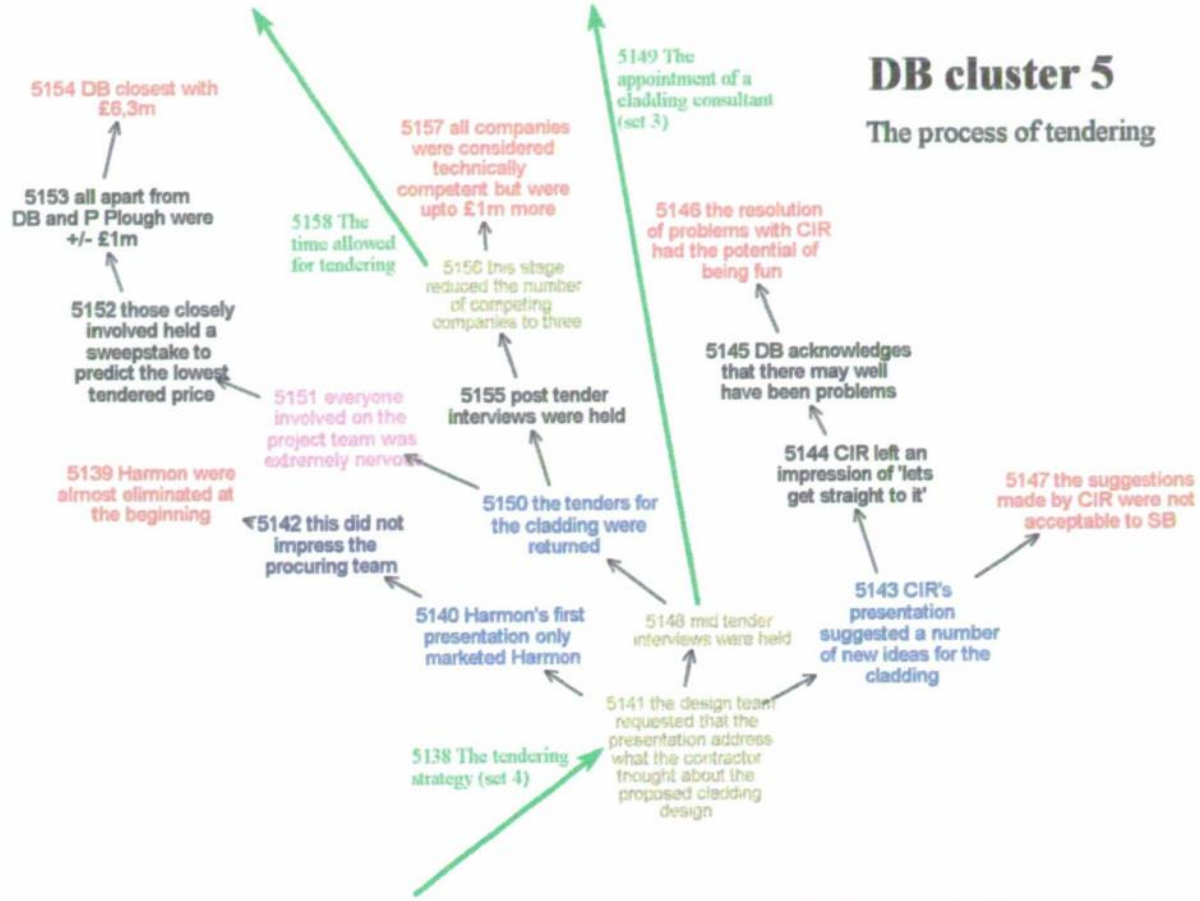


DB cluster 4

The tendering strategy

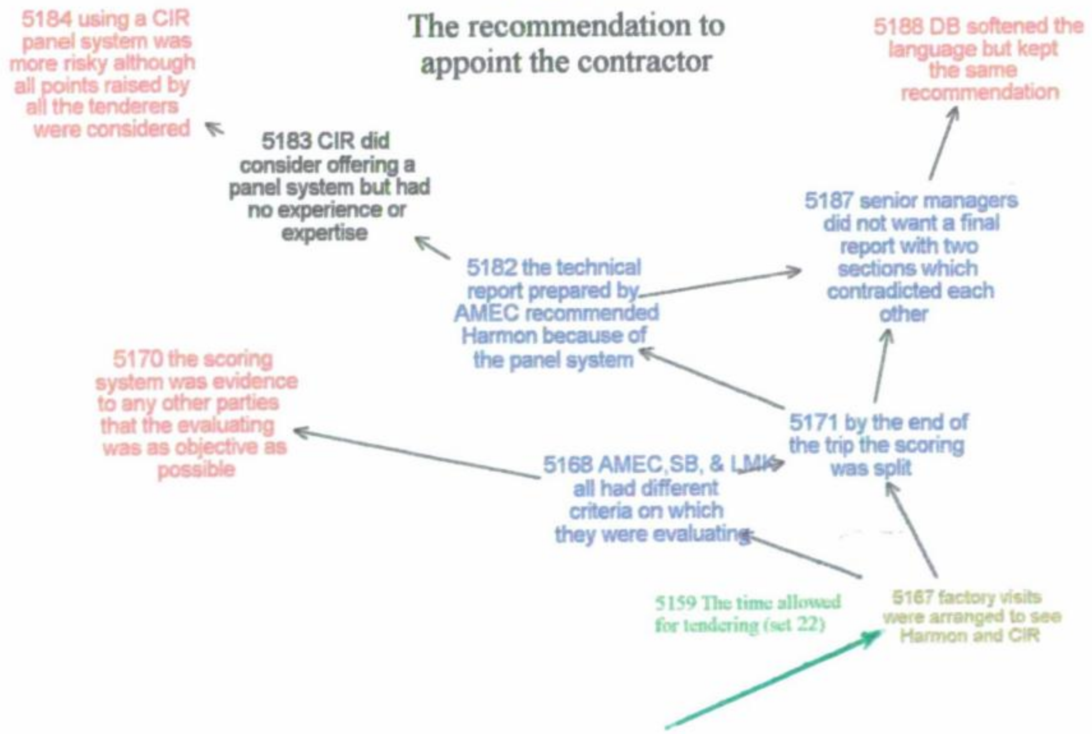
DB cluster 5

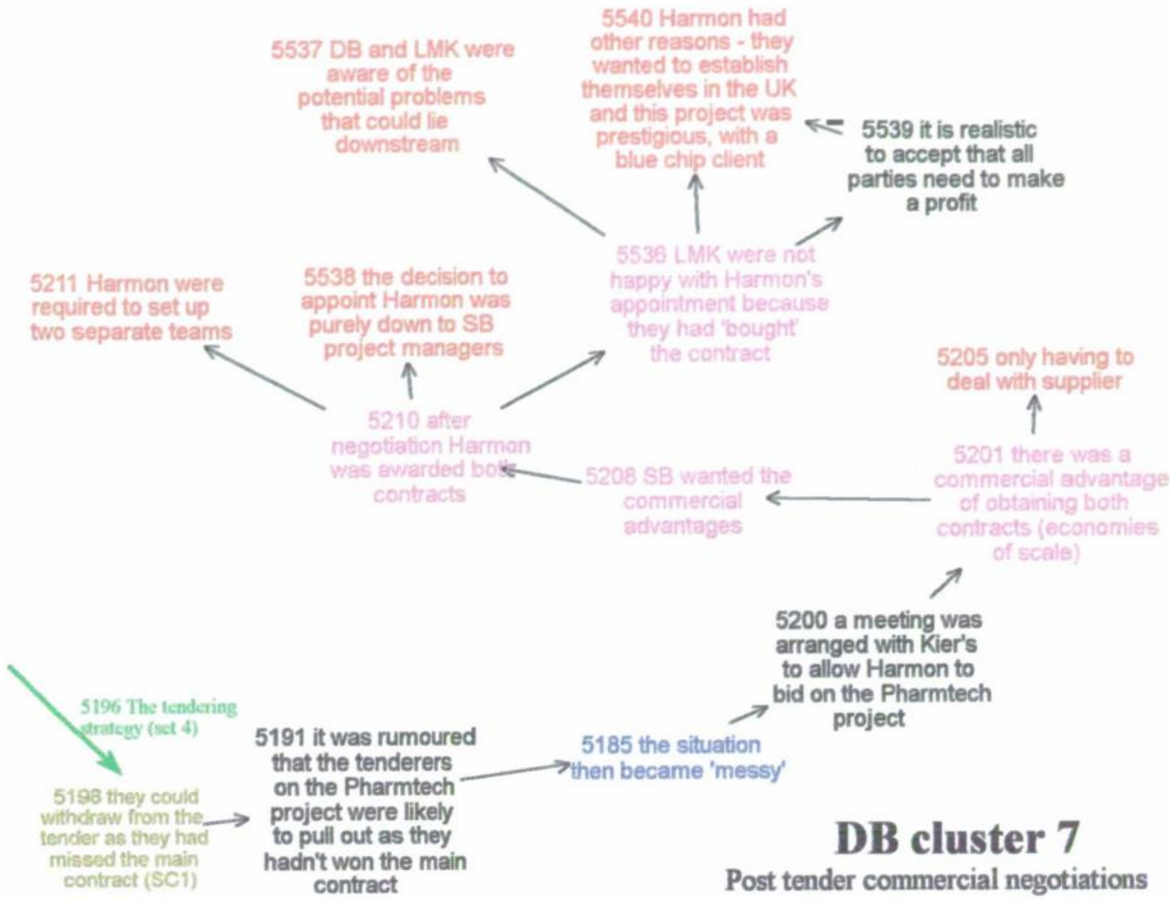
The process of tendering



DB cluster 6

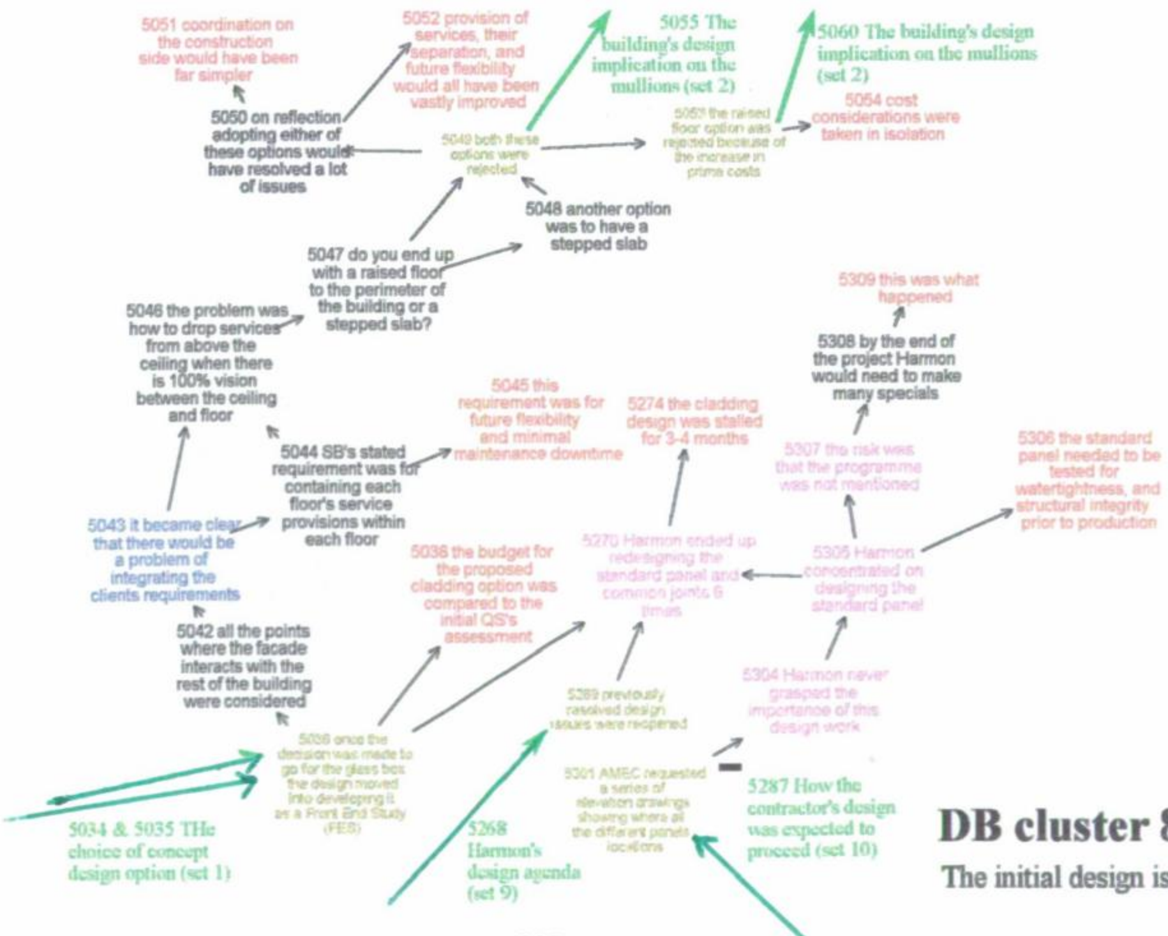
The recommendation to appoint the contractor





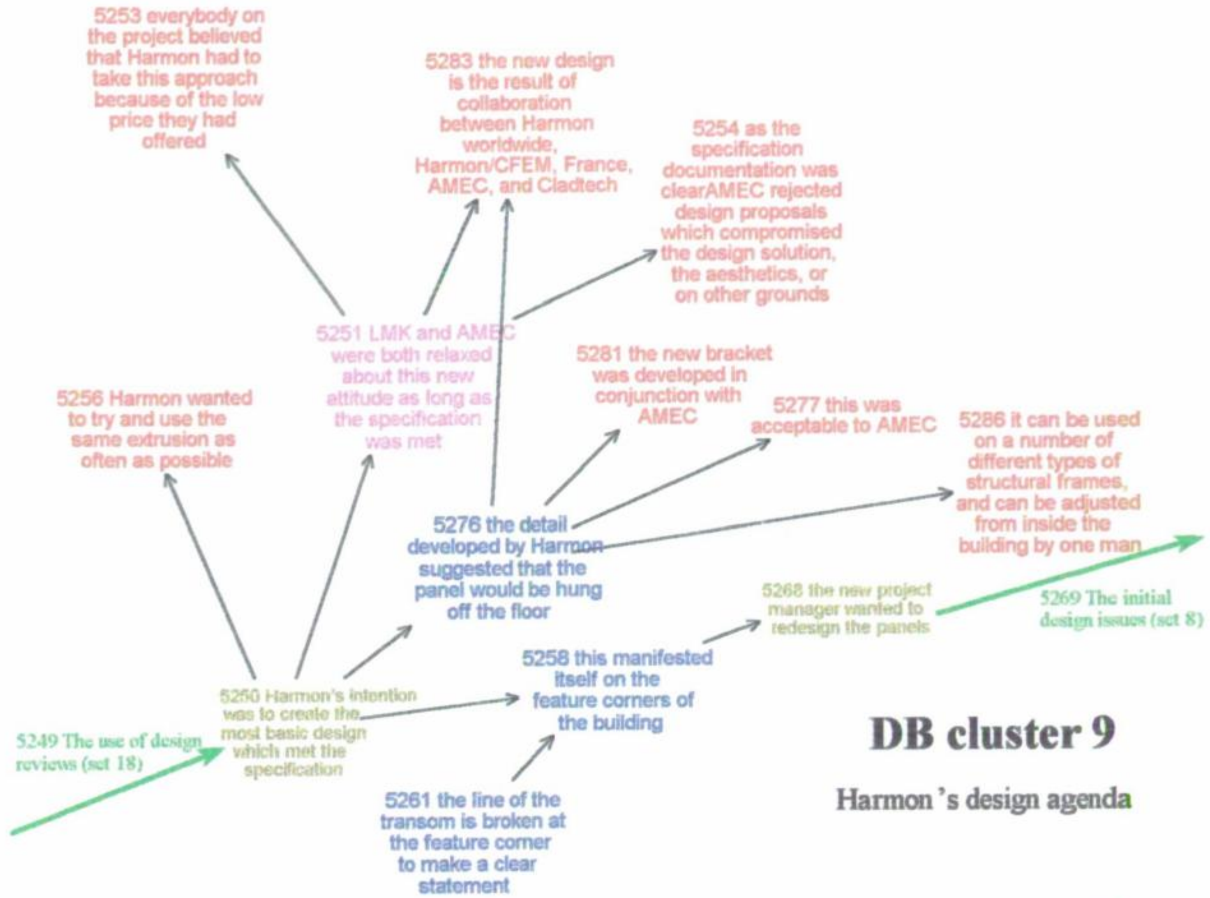
DB cluster 7

Post tender commercial negotiations



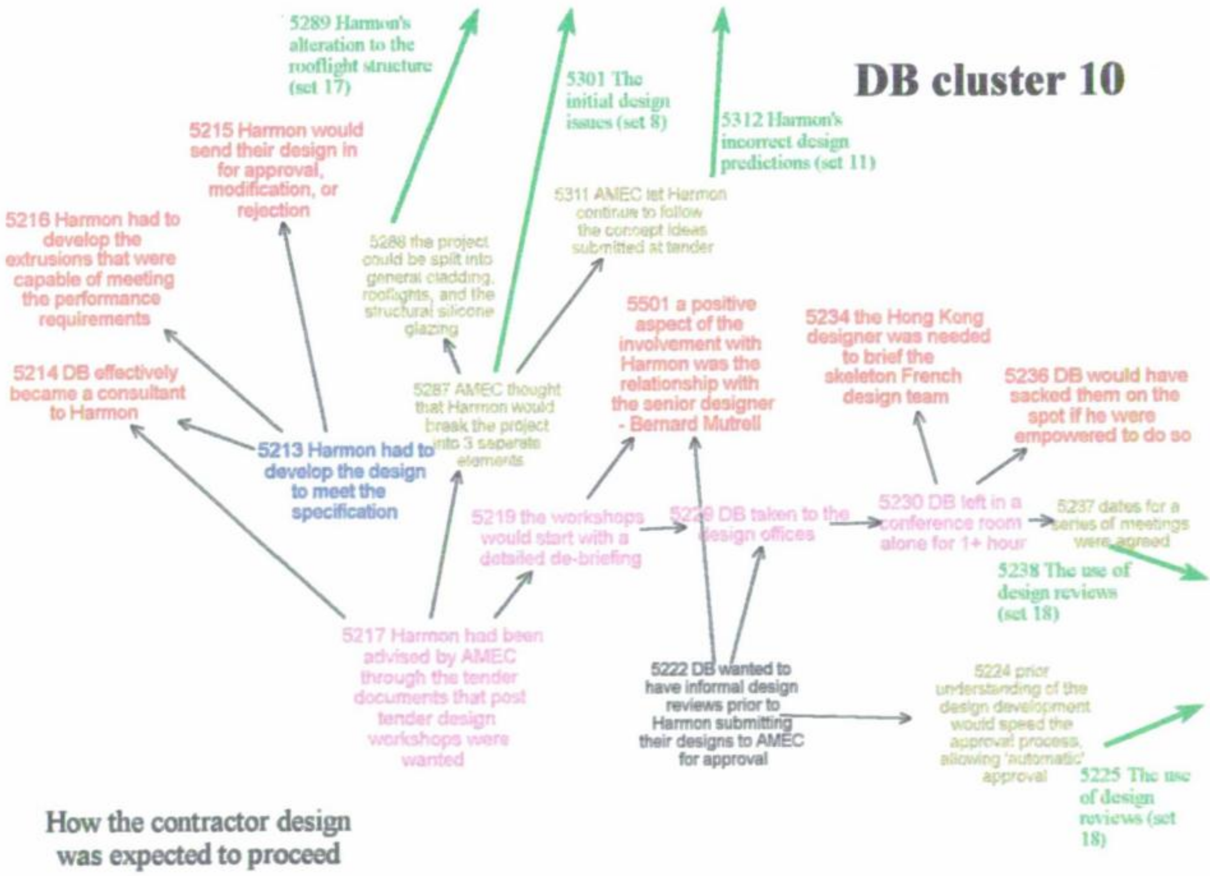
DB cluster 8

The initial design issues



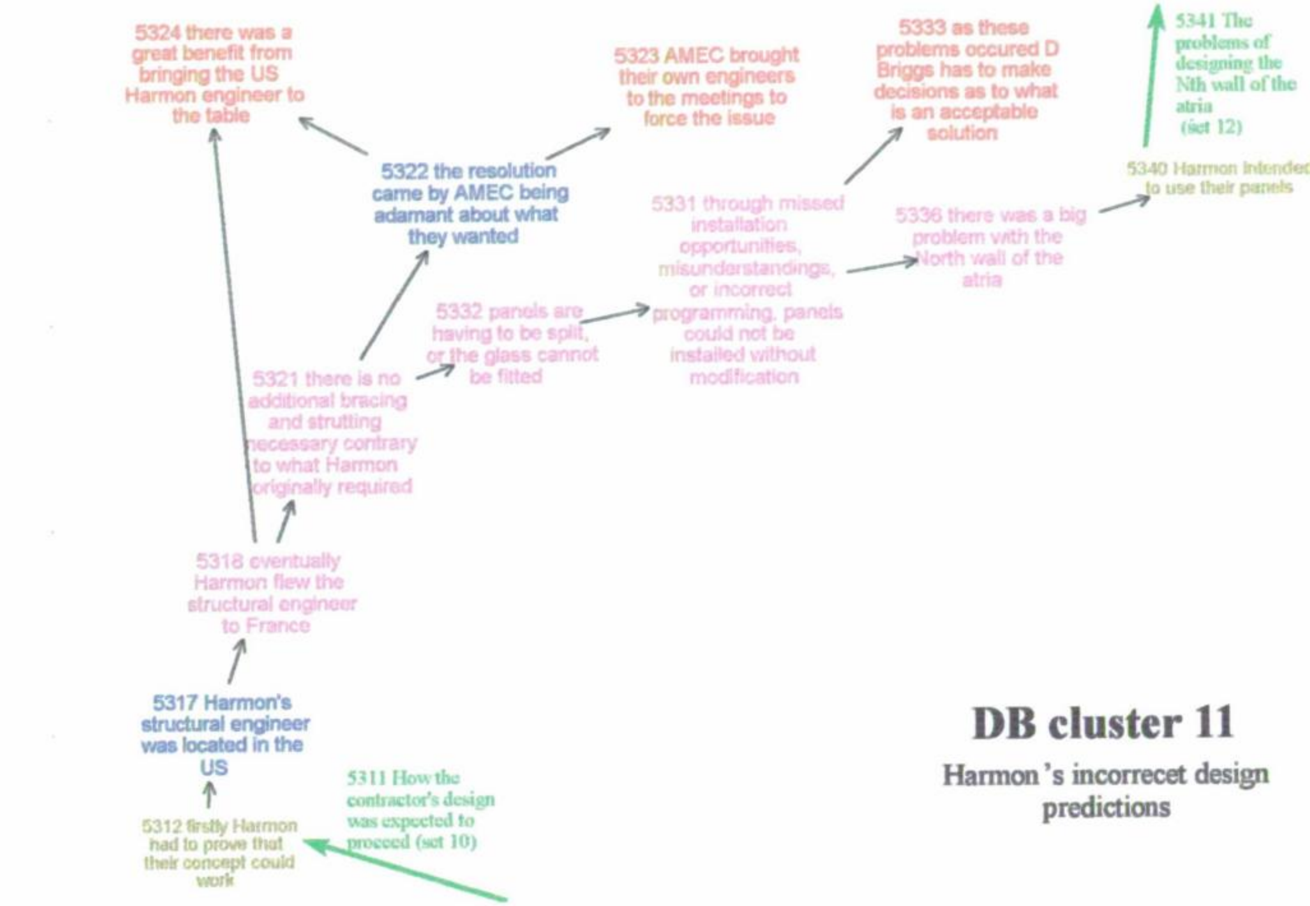
DB cluster 9

Harmon's design agenda



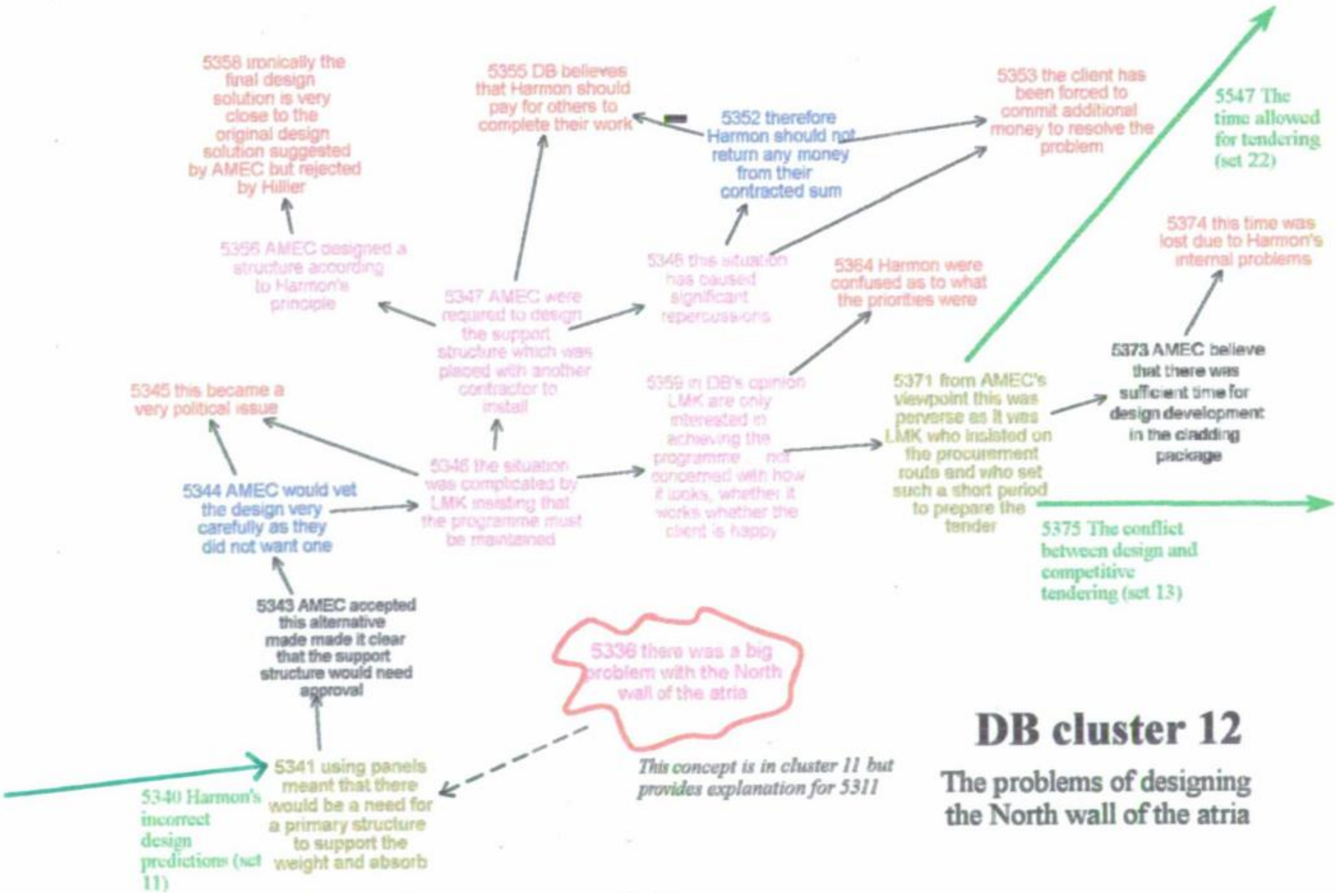
DB cluster 10

How the contractor design was expected to proceed



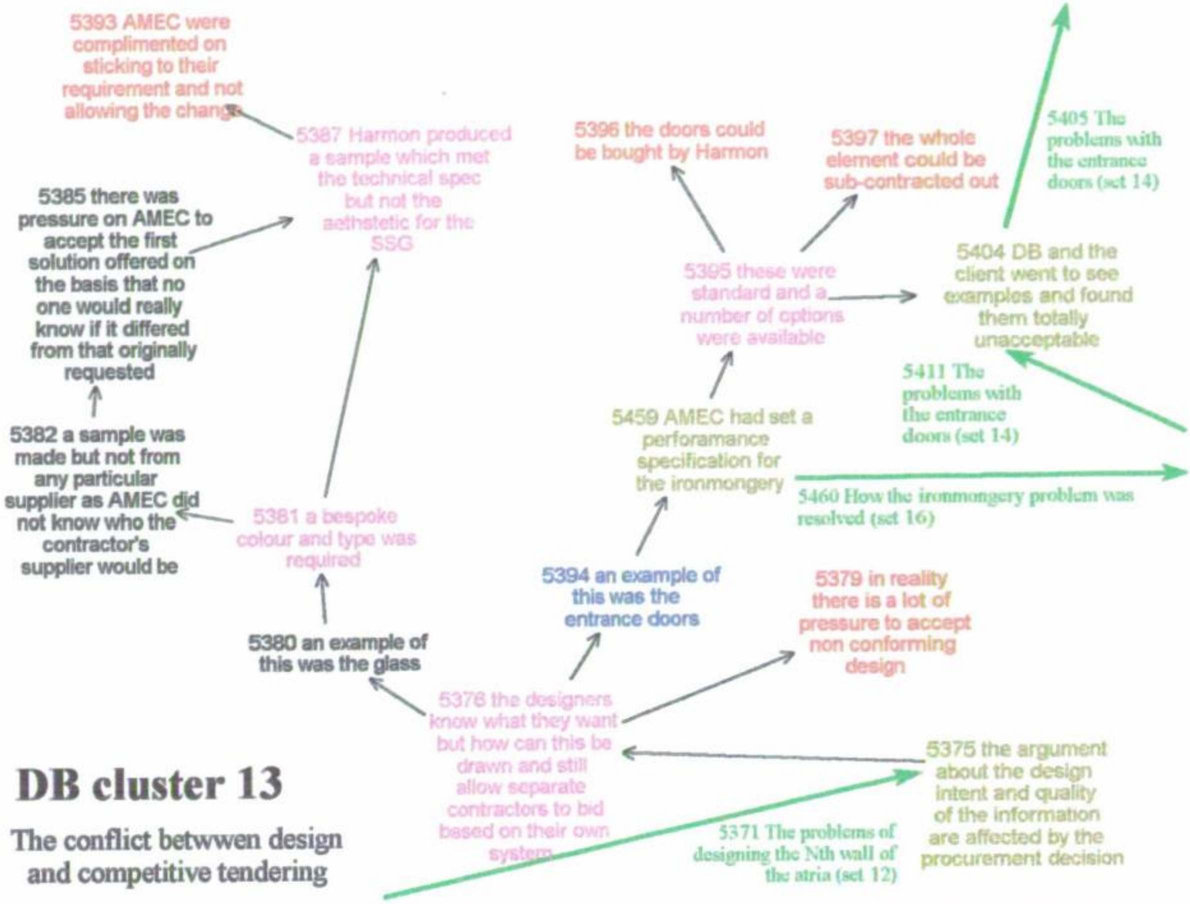
DB cluster 11

Harmon's incorrecet design predictions



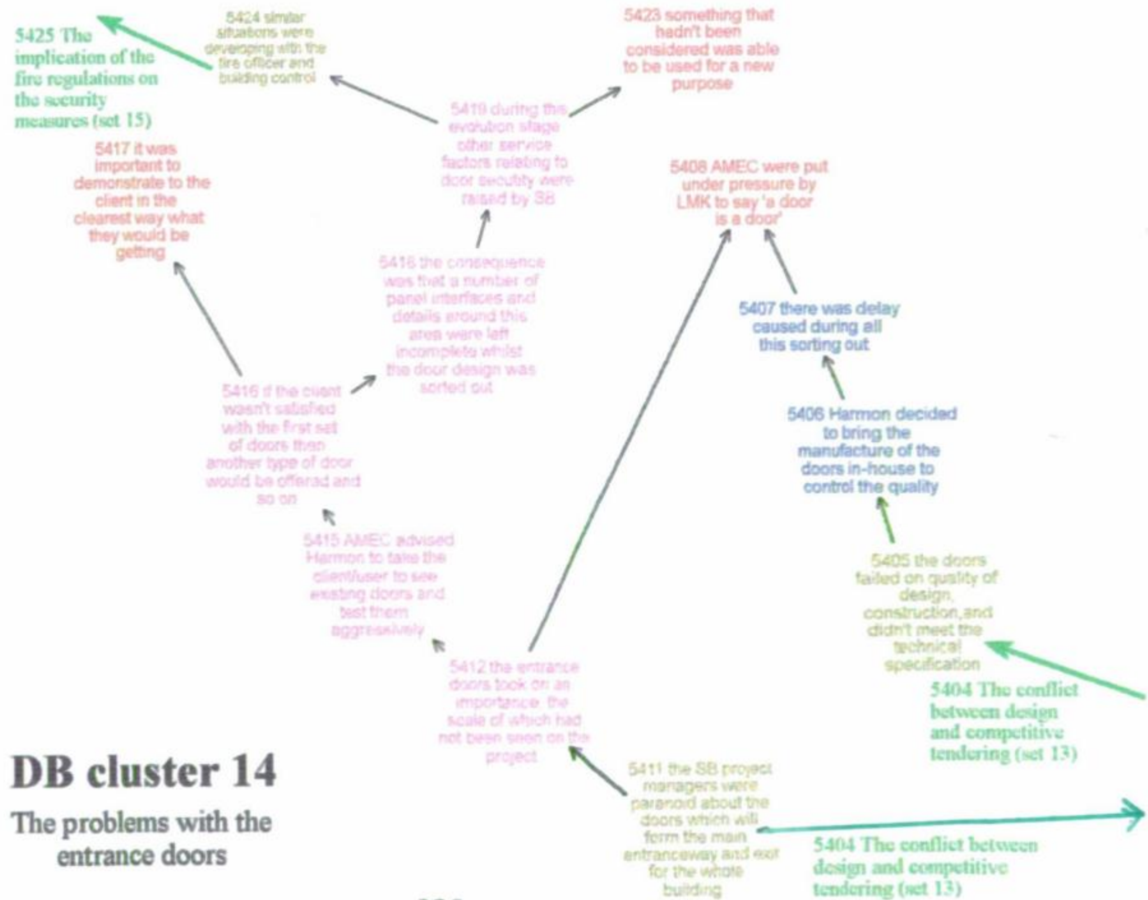
DB cluster 12

The problems of designing the North wall of the atria



DB cluster 13

The conflict betwwen design and competitive tendering



DB cluster 14

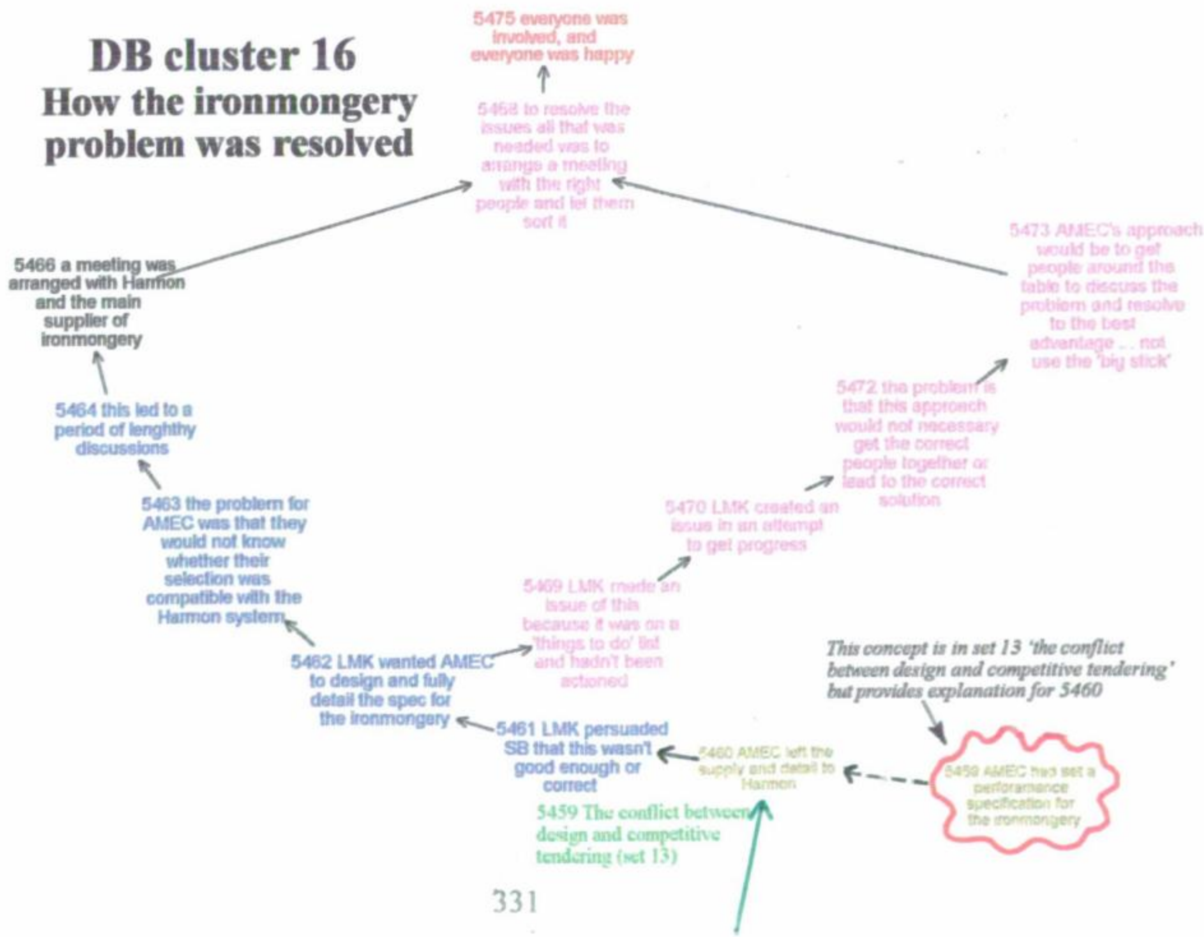
The problems with the entrance doors

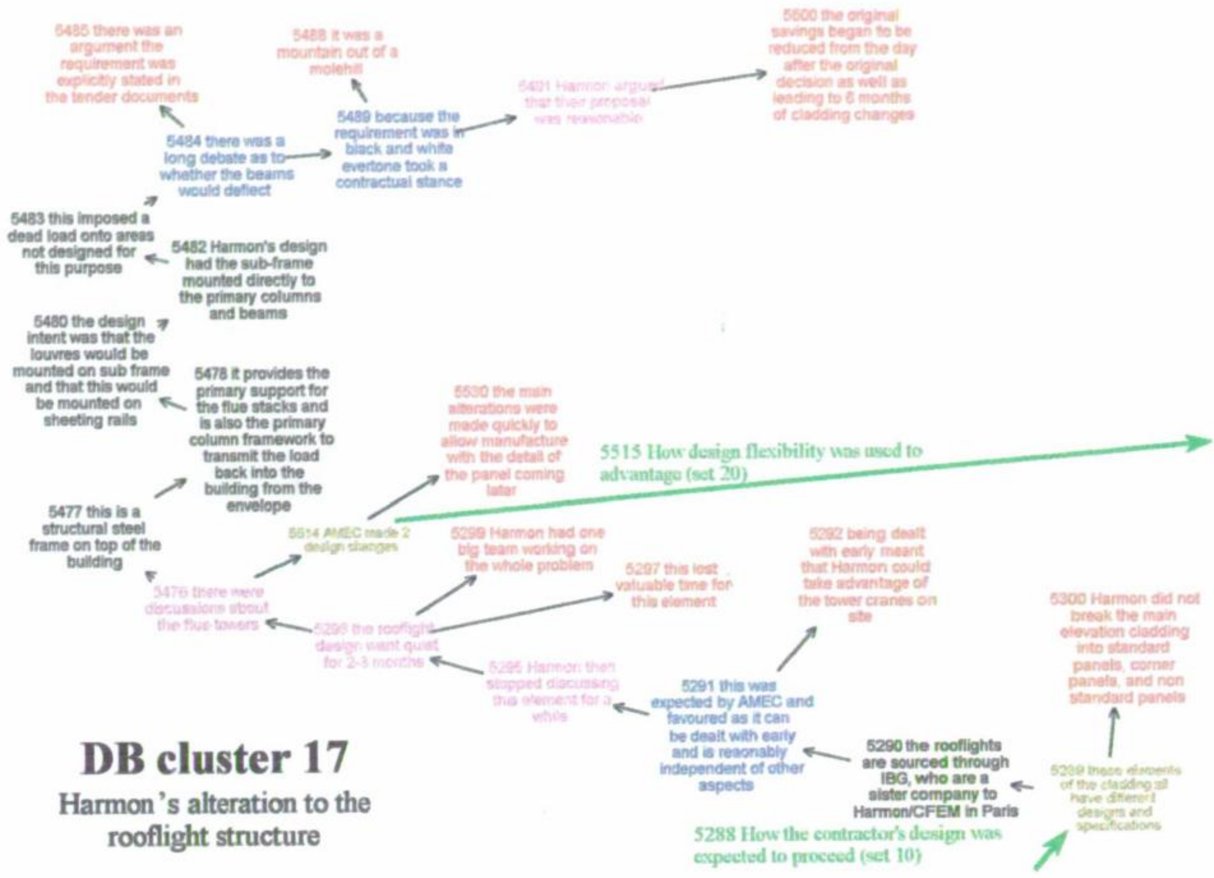
DB cluster 15

The implication of the fire regulations on the security measures

DB cluster 16

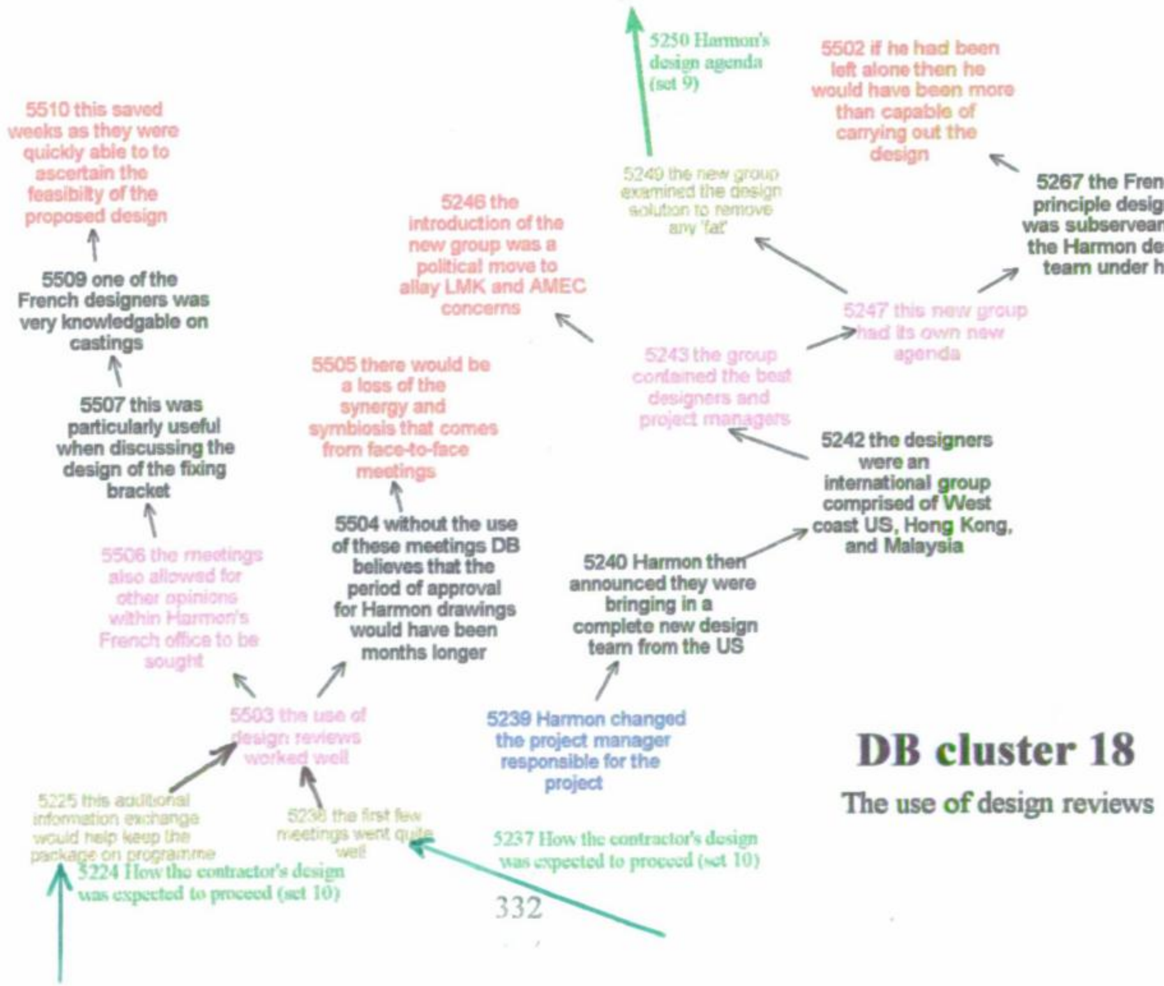
How the ironmongery problem was resolved





DB cluster 17

Harmon's alteration to the rooflight structure



DB cluster 18

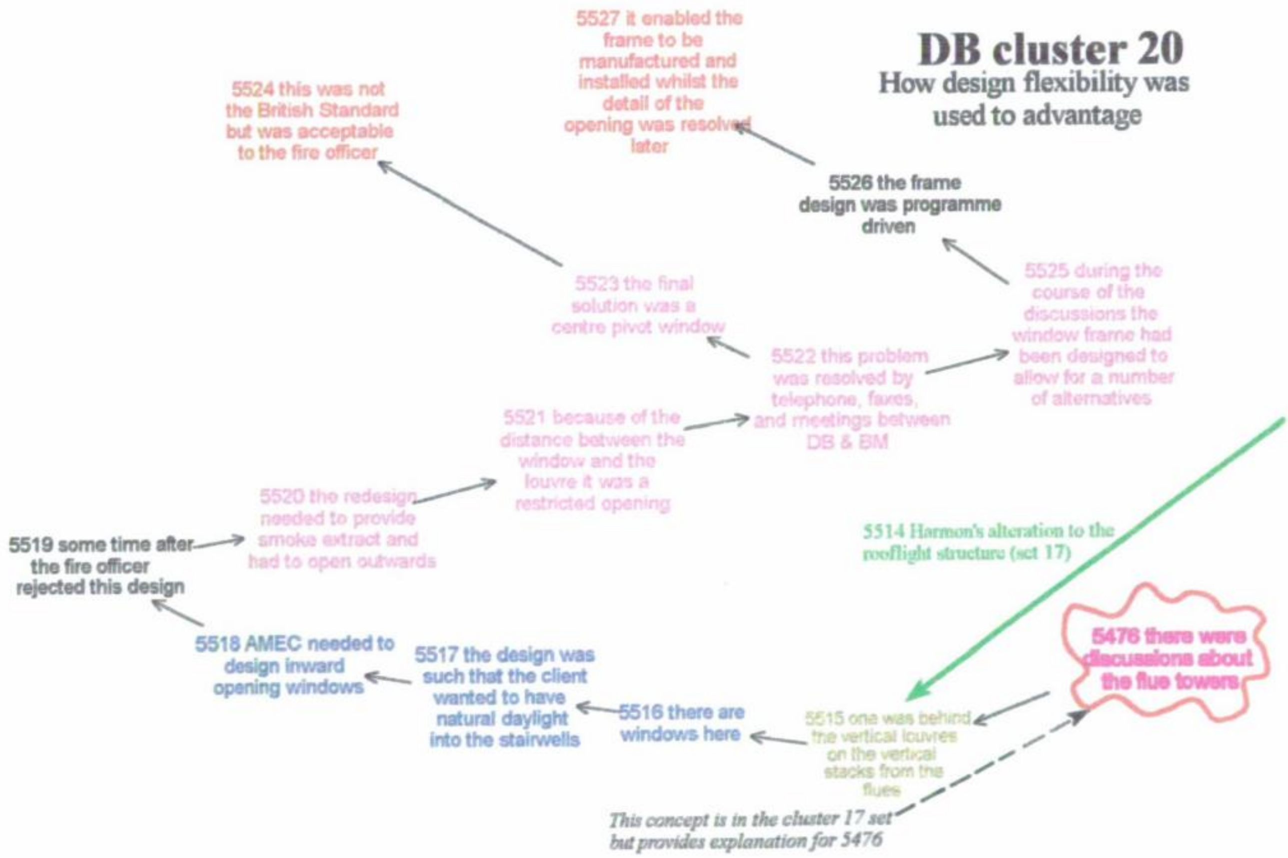
The use of design reviews

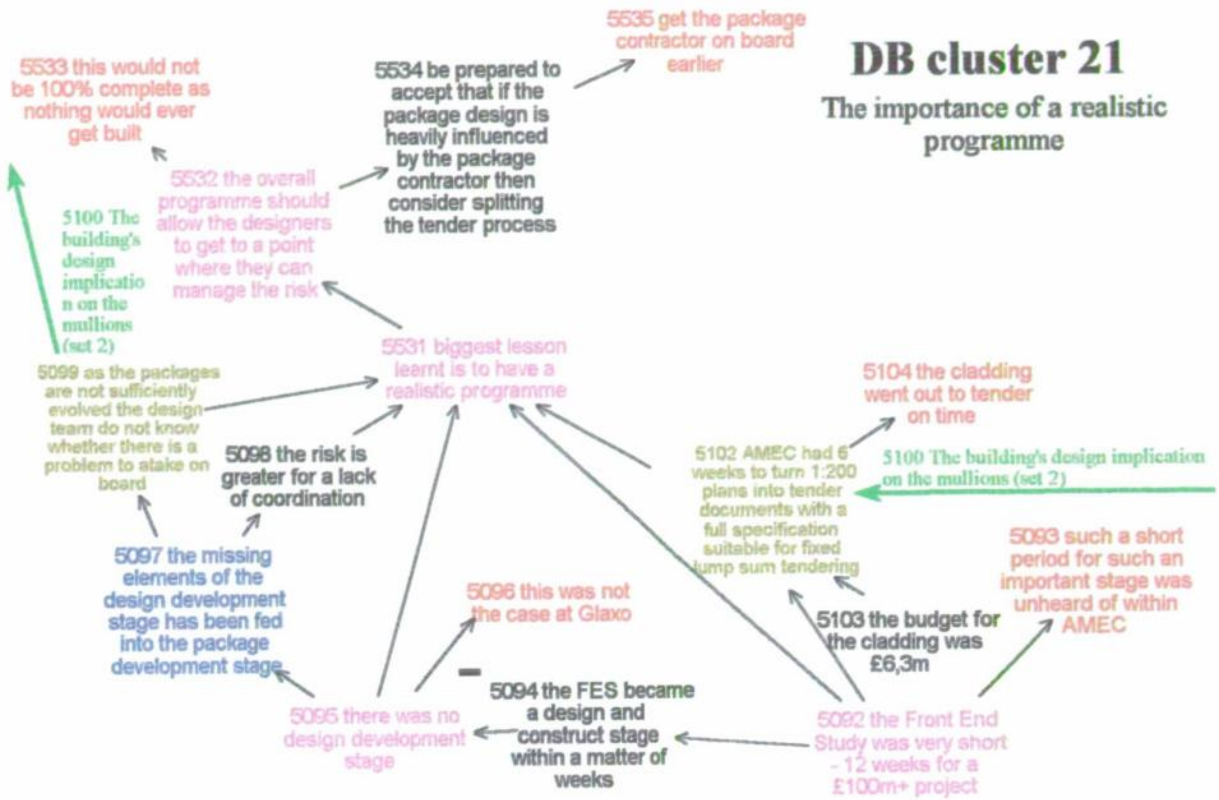
DB cluster 19

What the client has achieved

DB cluster 20

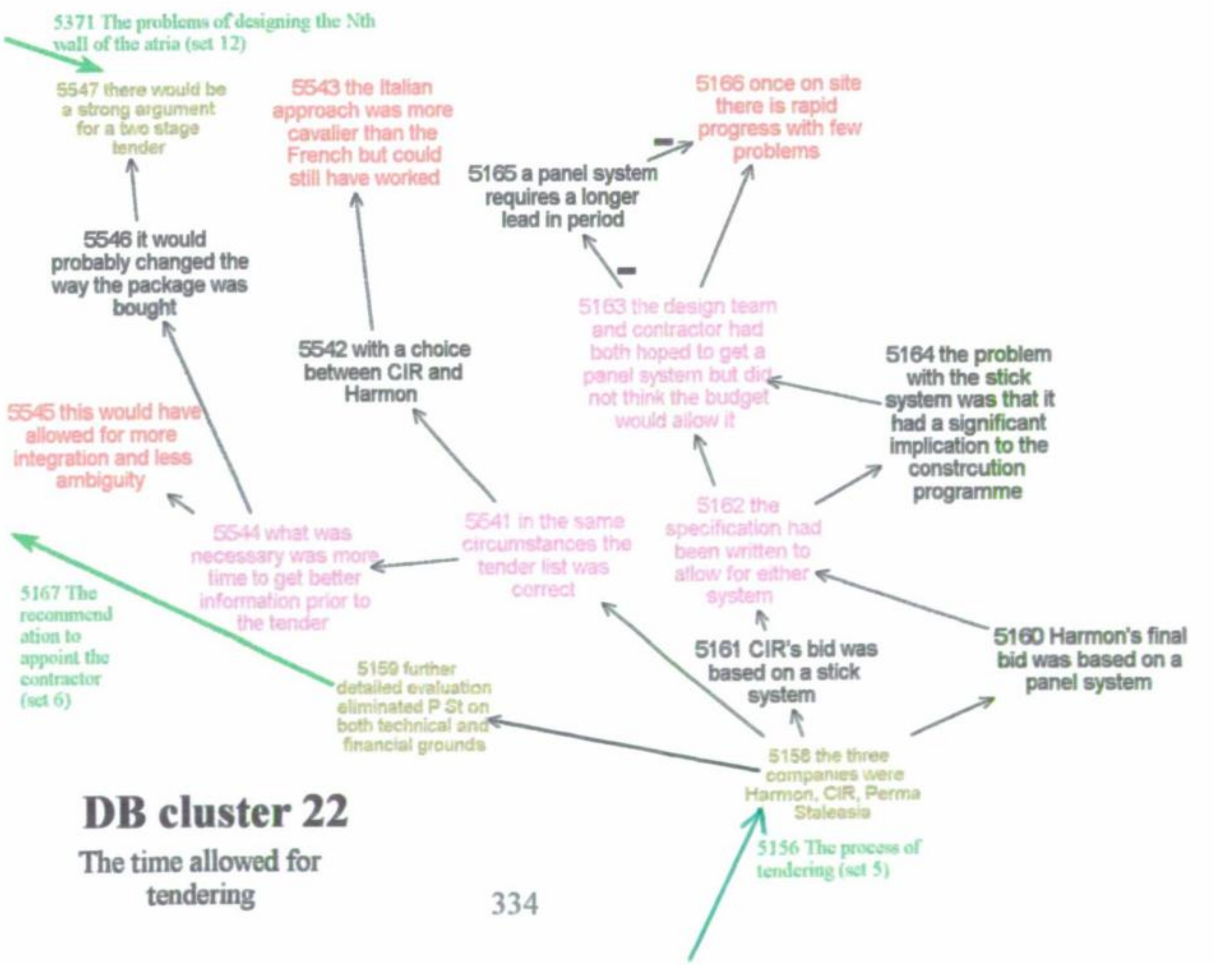
How design flexibility was used to advantage





DB cluster 21

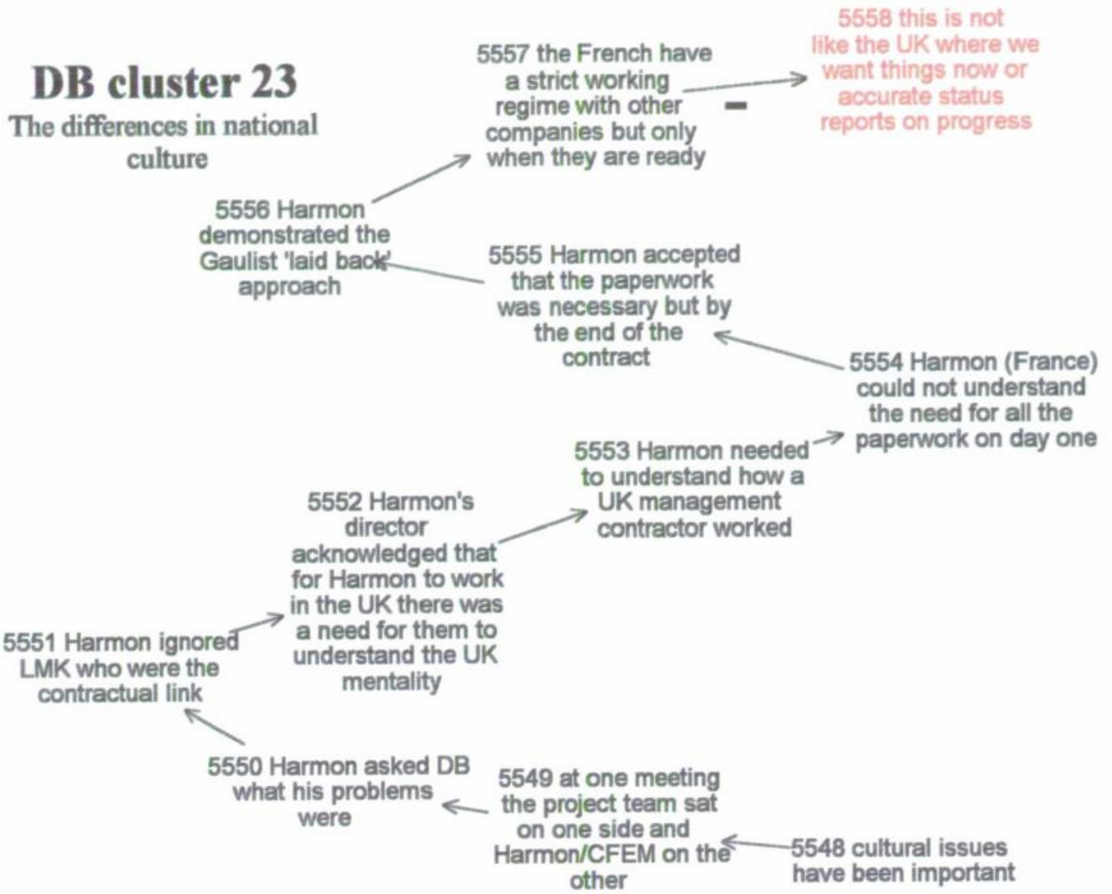
The importance of a realistic programme



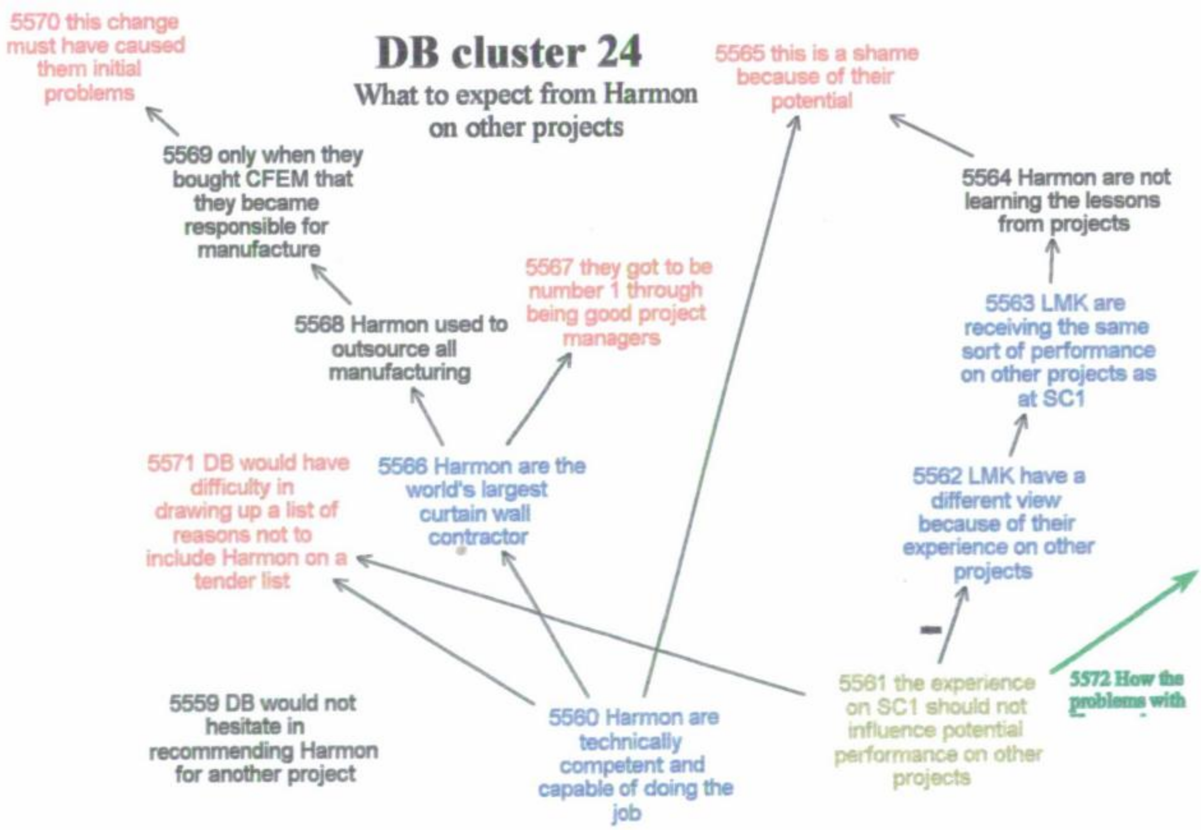
DB cluster 22

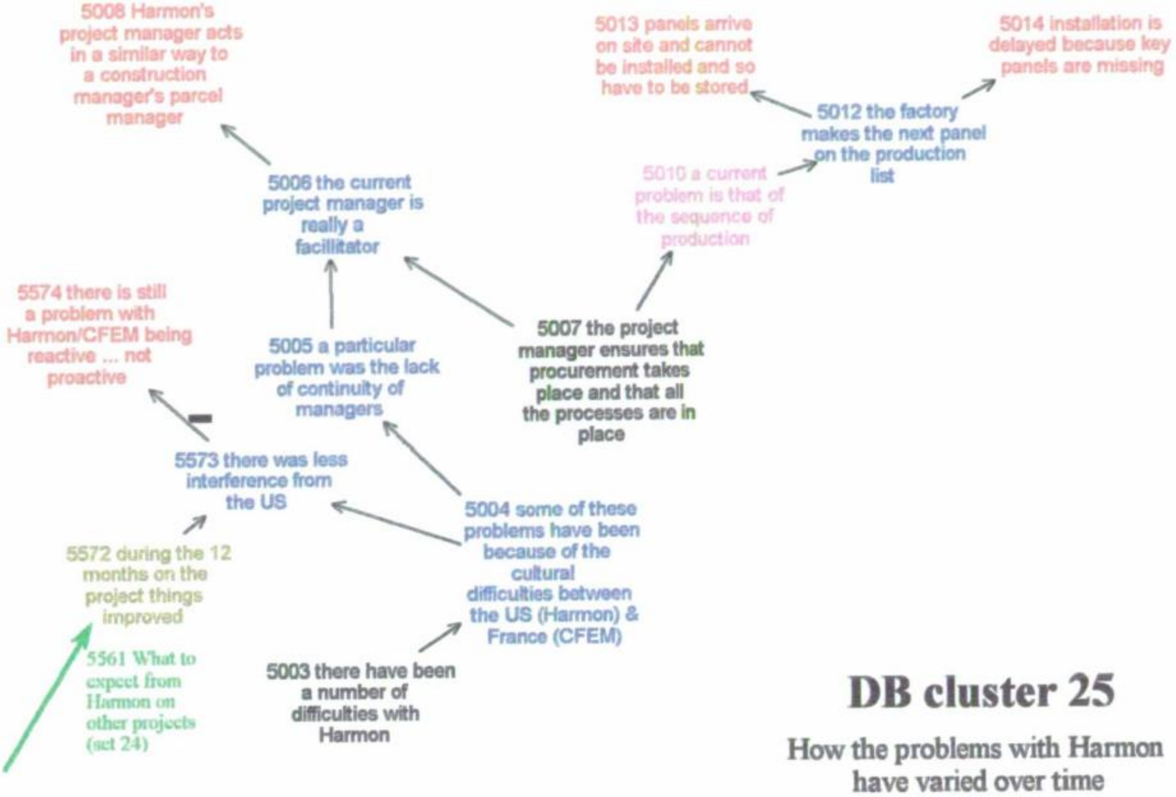
The time allowed for tendering

DB cluster 23
The differences in national culture



DB cluster 24
What to expect from Harmon on other projects



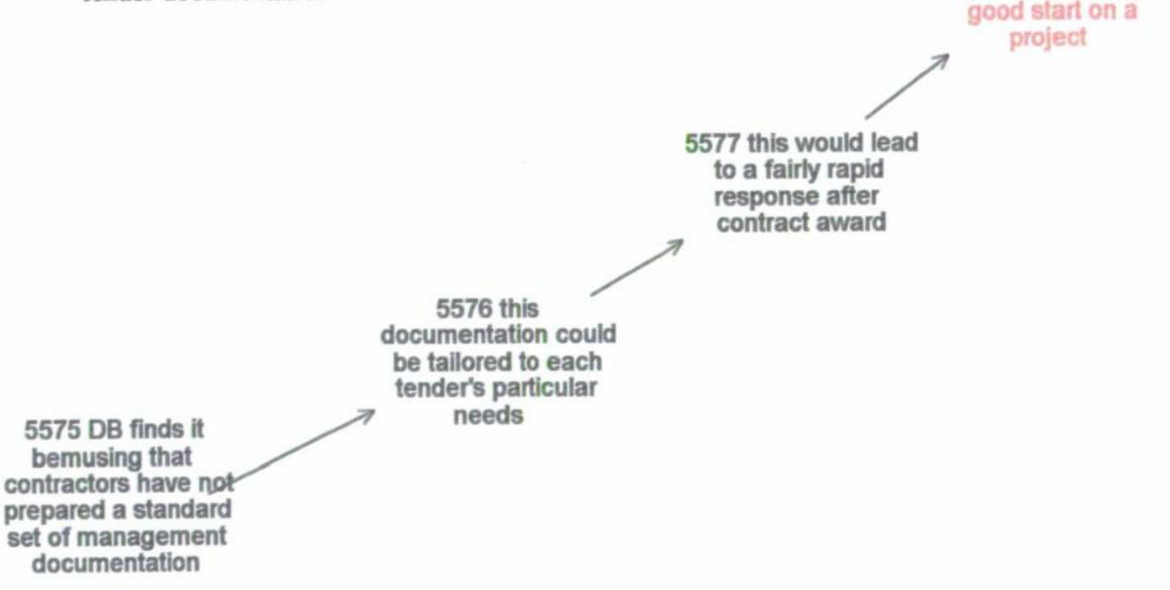


DB cluster 25

How the problems with Harmon have varied over time

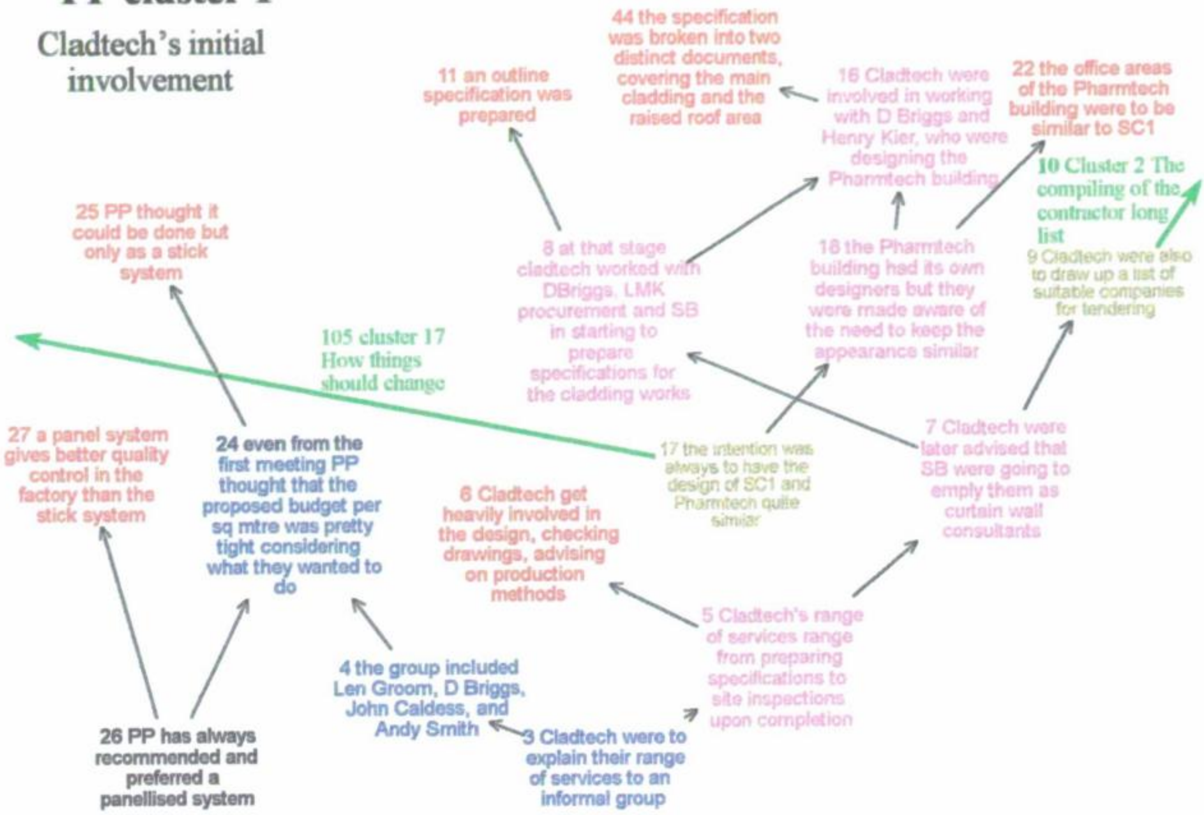
DB cluster 26

Contractors lack of standard tender documentation



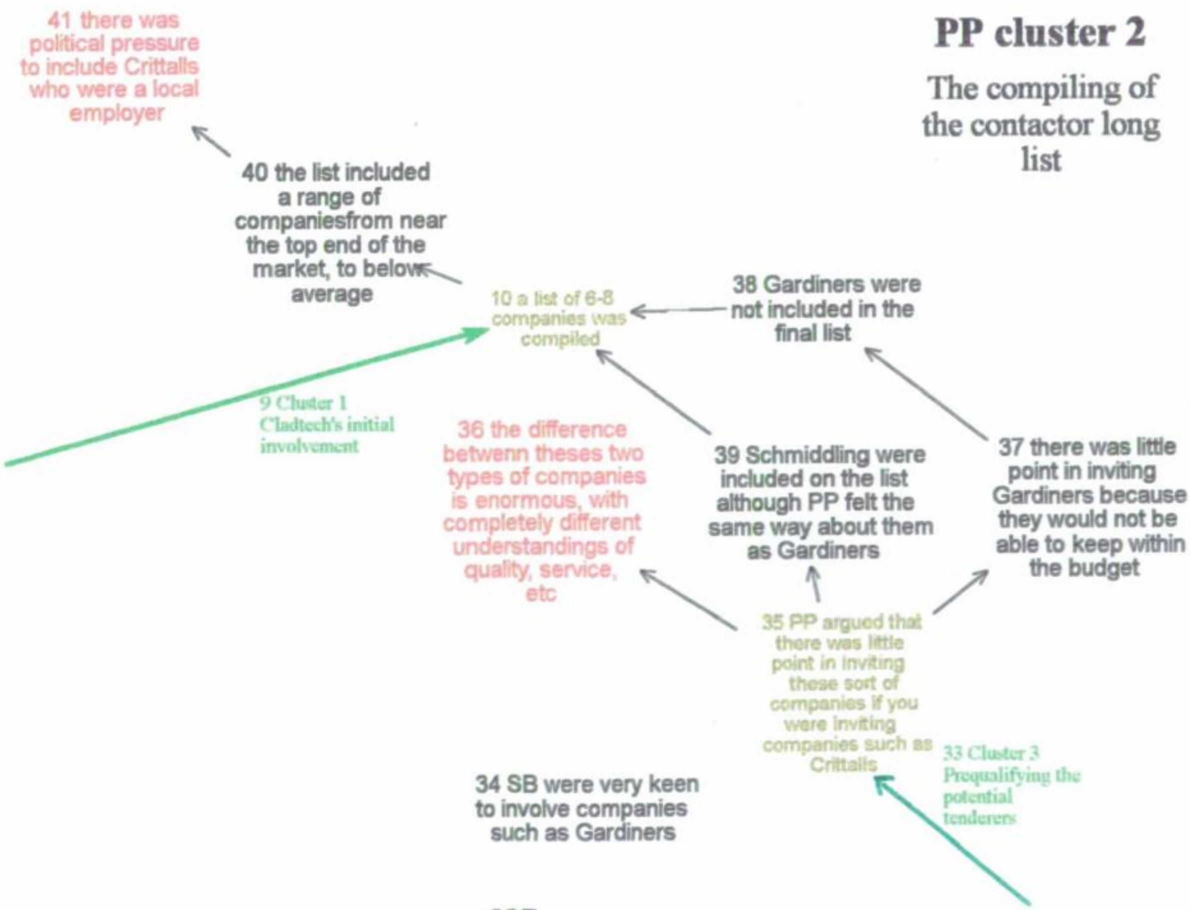
PP cluster 1

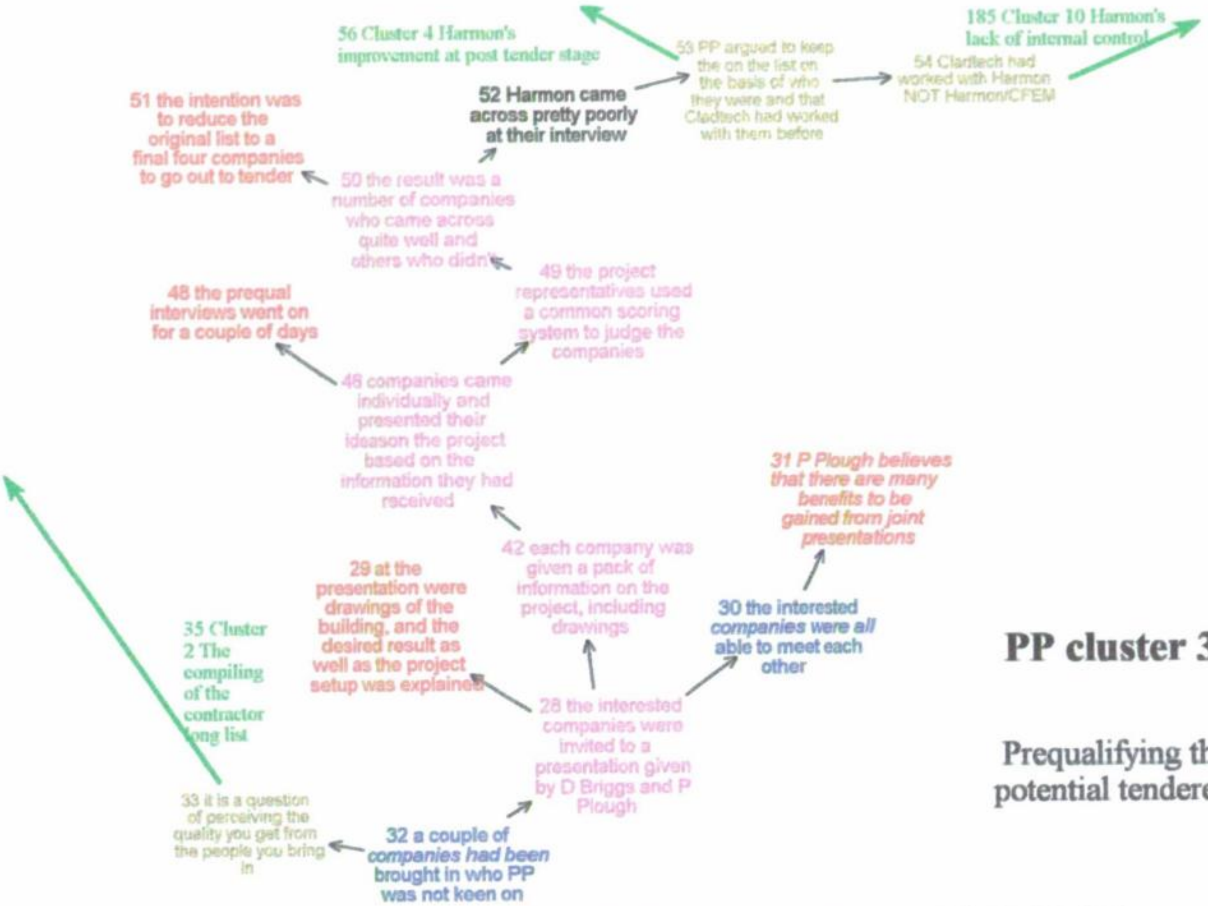
Cladtech's initial involvement



PP cluster 2

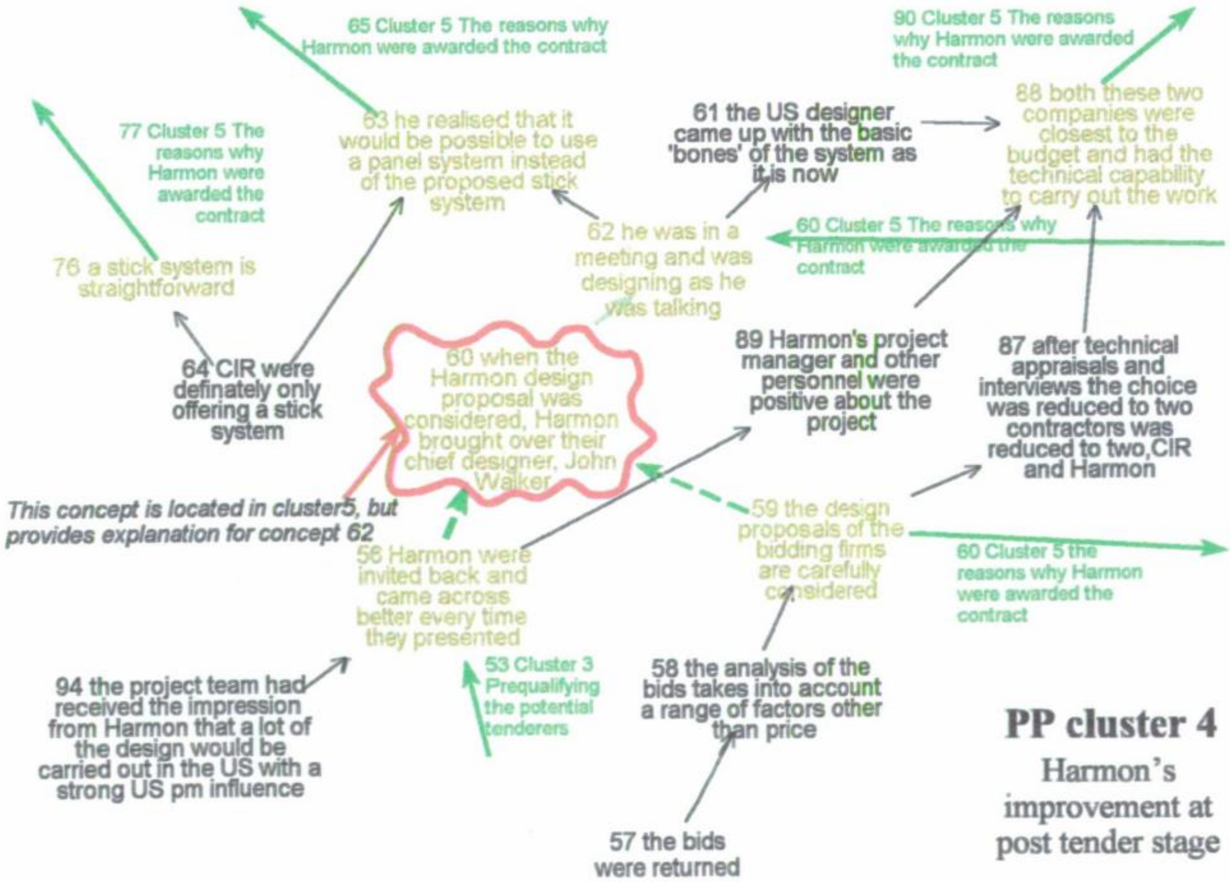
The compiling of the contactor long list





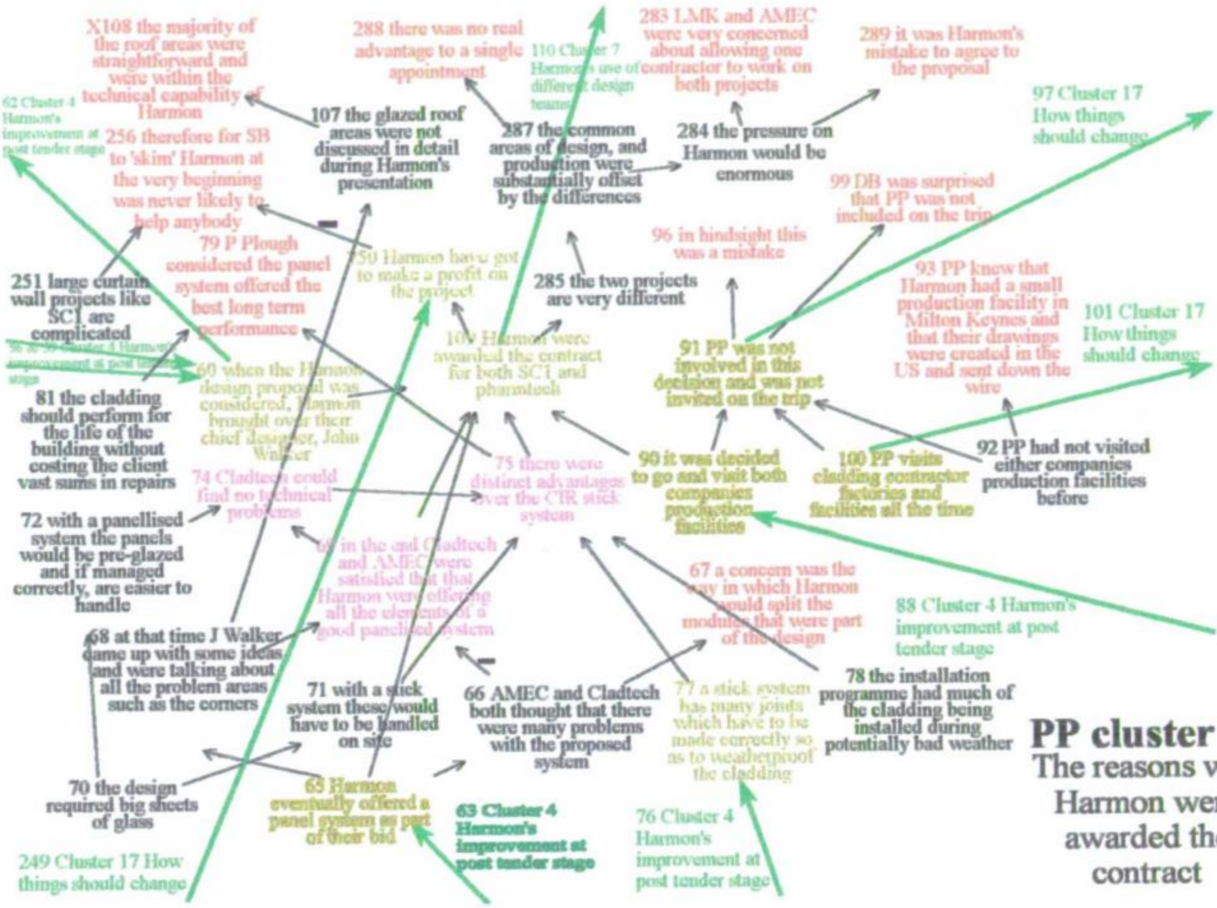
PP cluster 3

Prequalifying the potential tenderers



PP cluster 4

Harmon's improvement at post tender stage

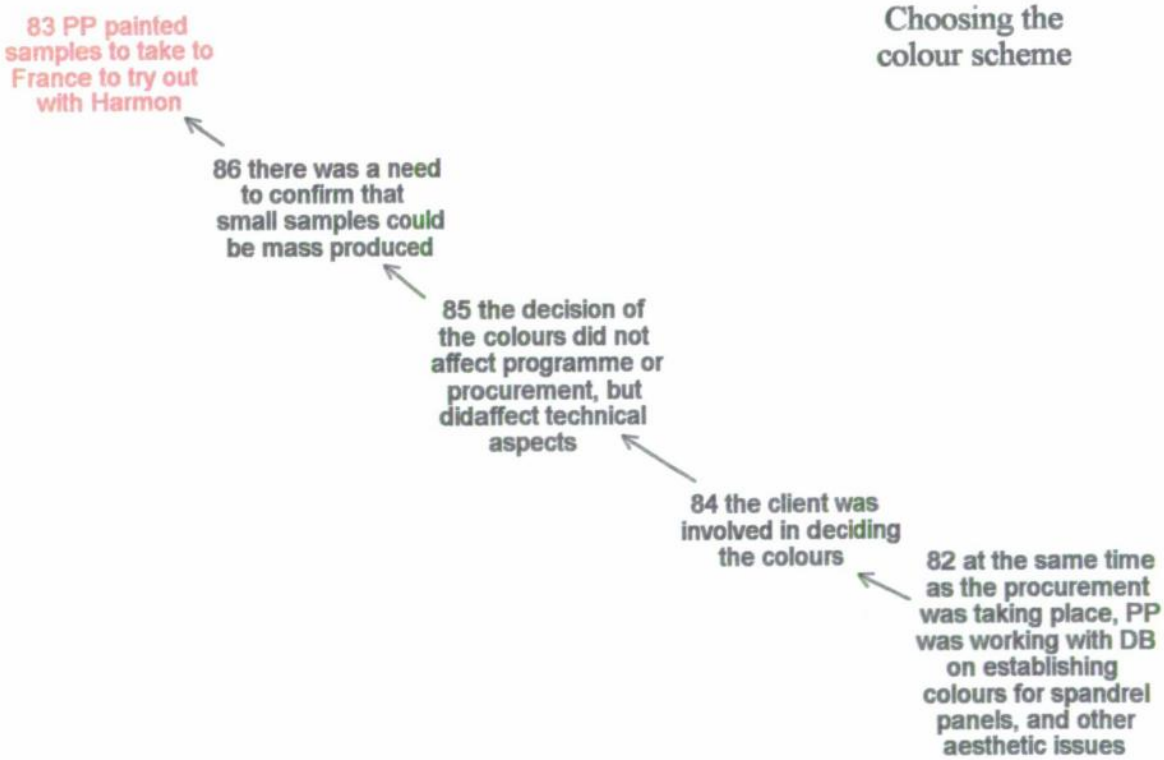


PP cluster 5

The reasons why Harmon were awarded the contract

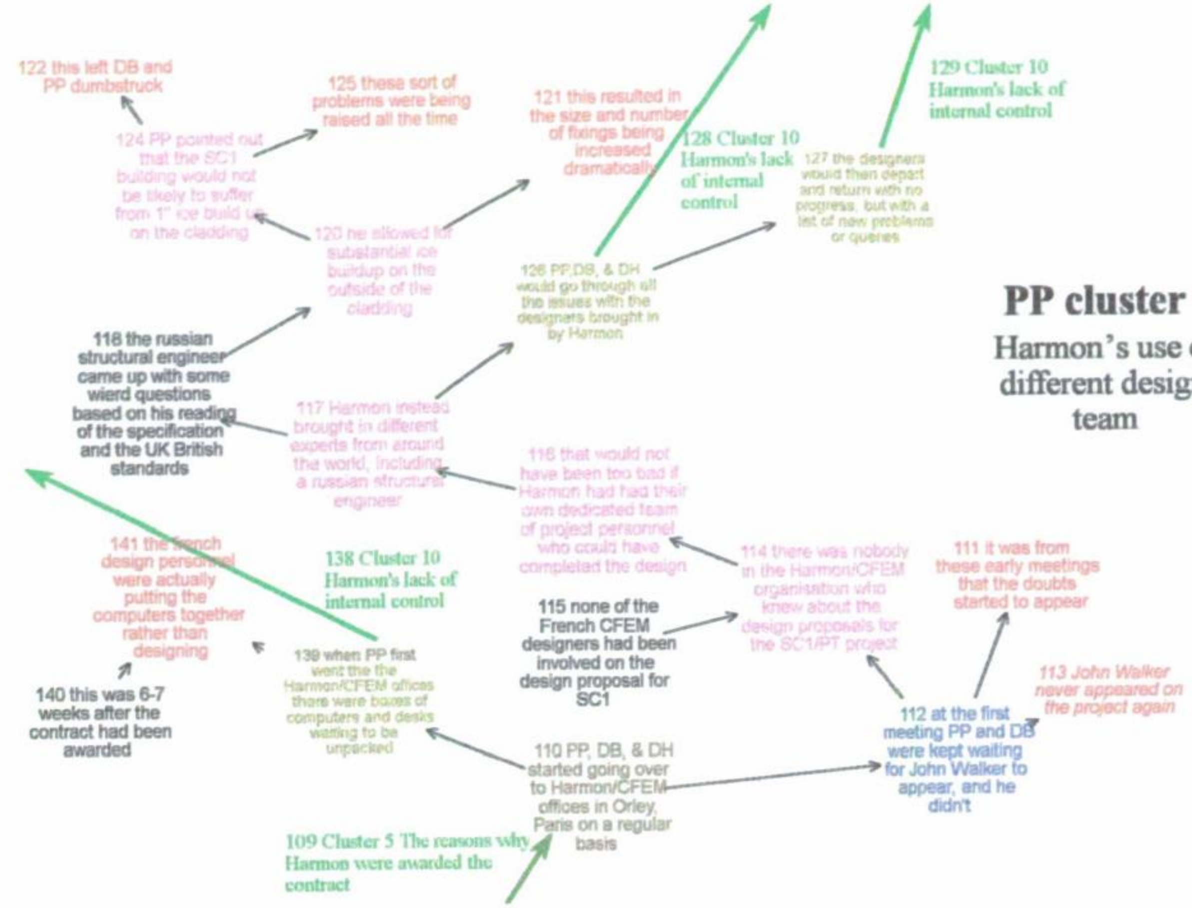
PP cluster 6

Choosing the colour scheme



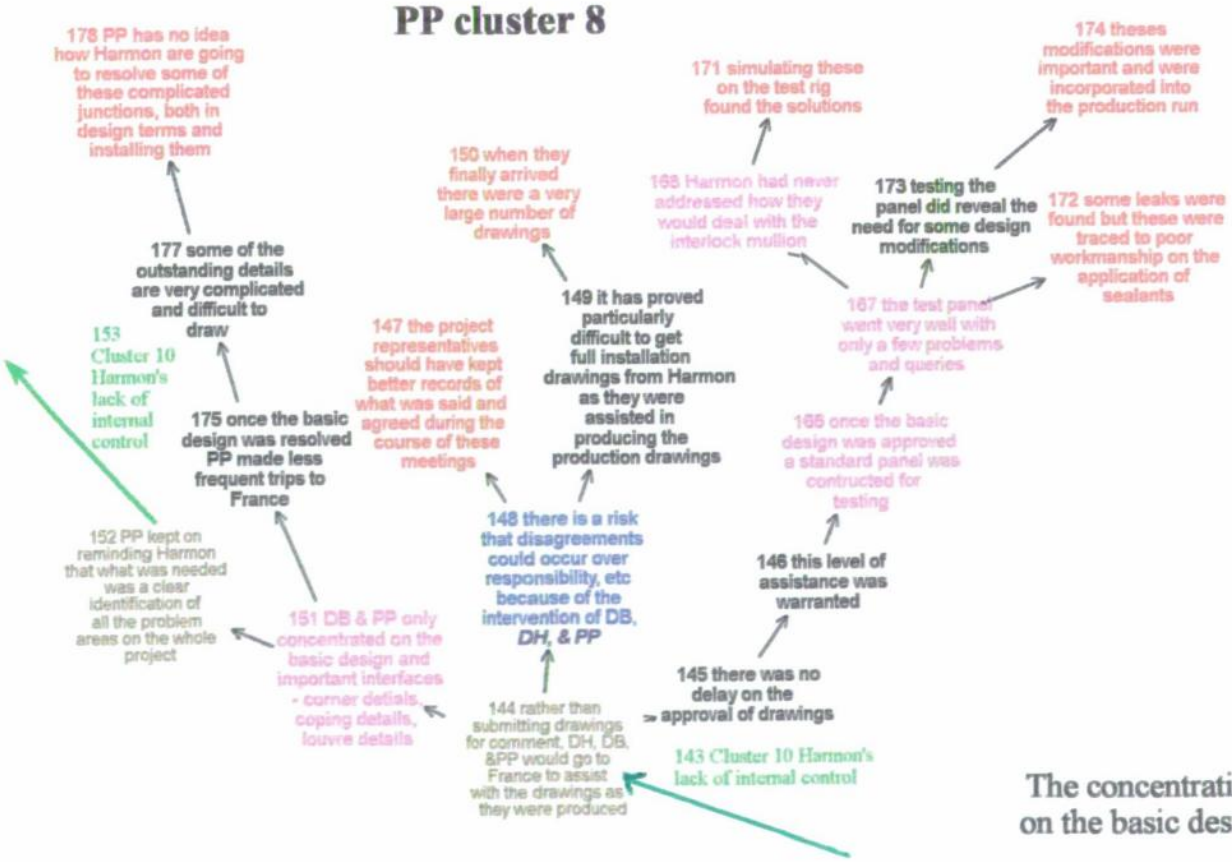
PP cluster 7

Harmon's use of different design team



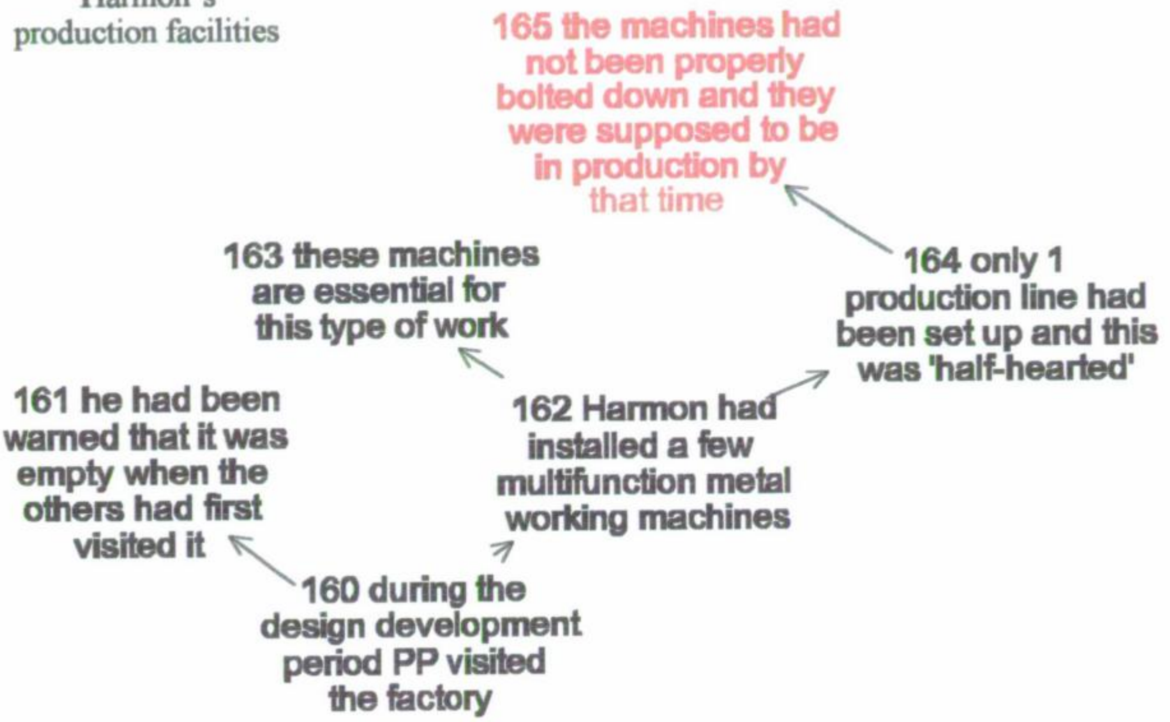
PP cluster 8

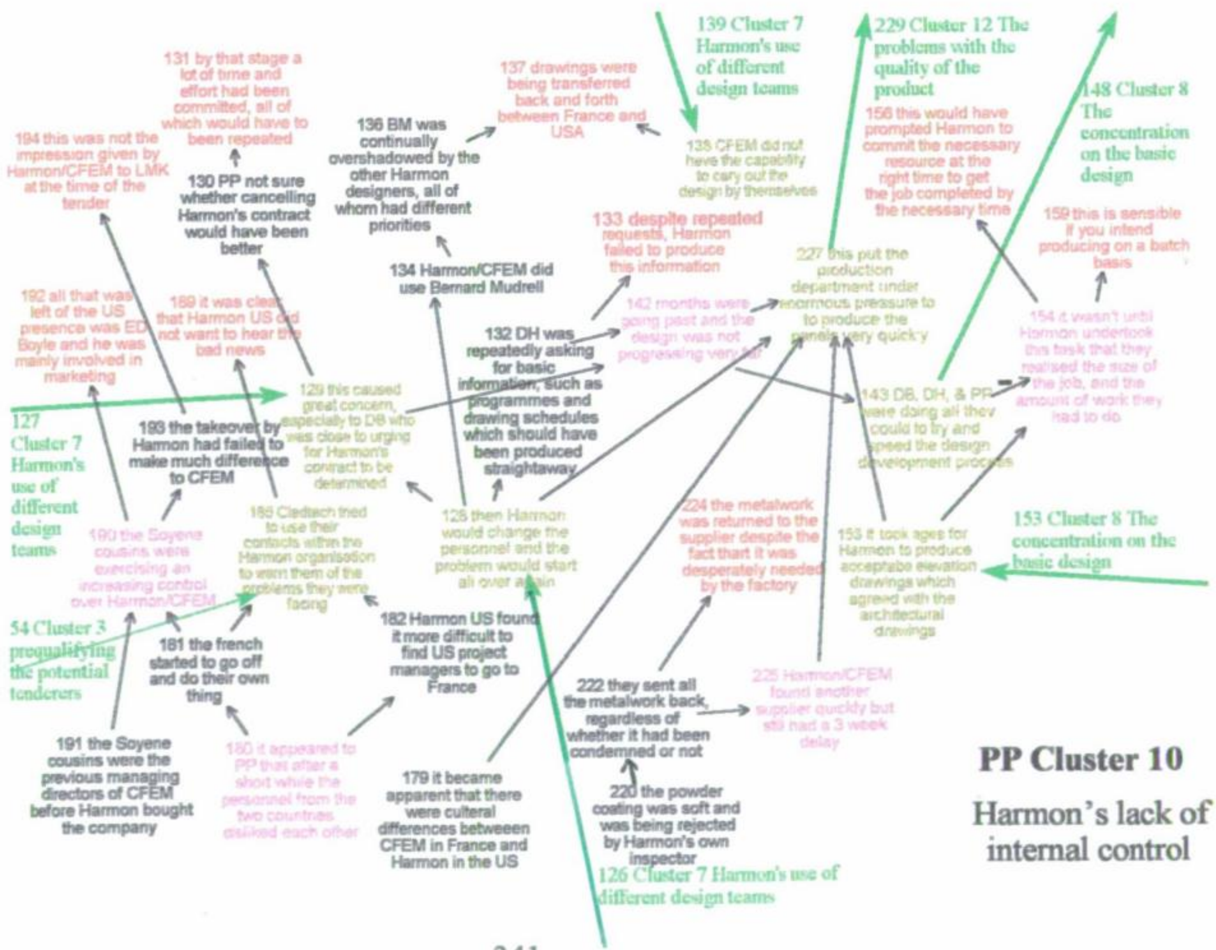
The concentration on the basic design



PP cluster 9

Harmon's production facilities

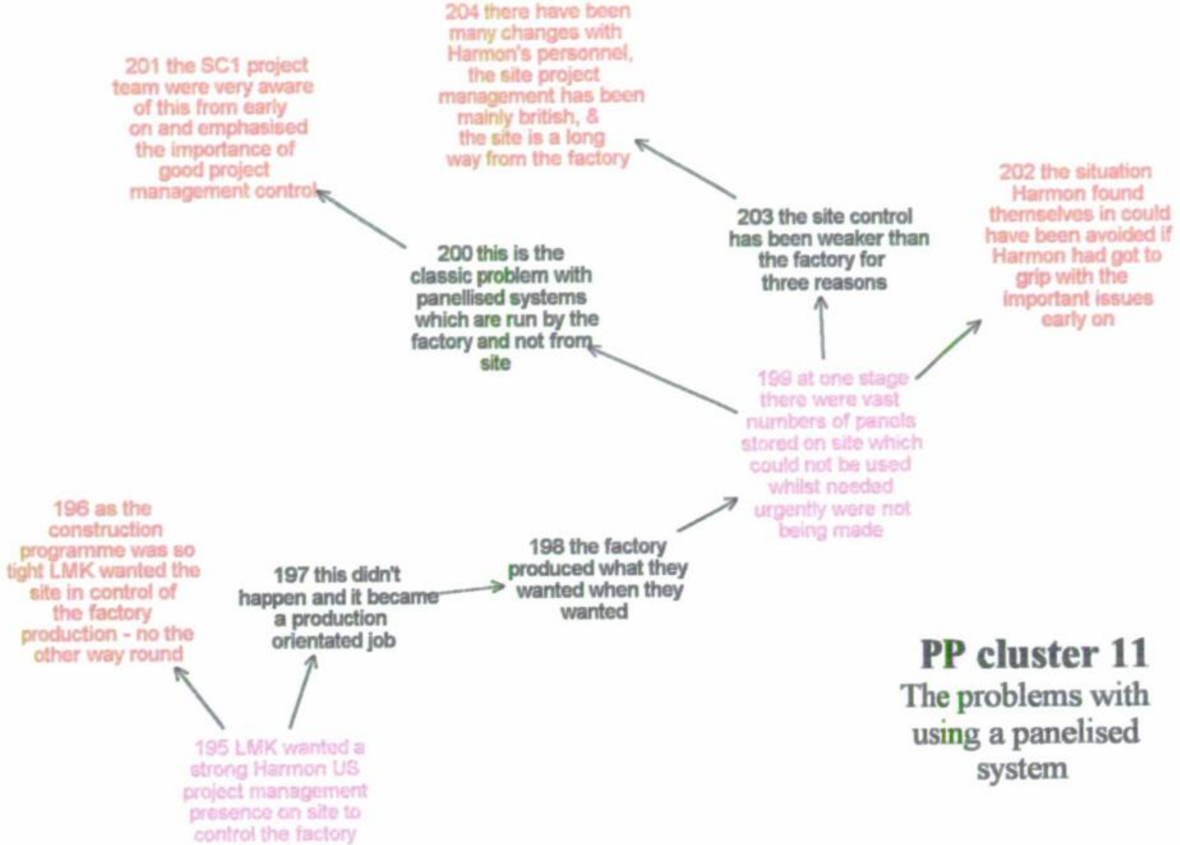




PP Cluster 10

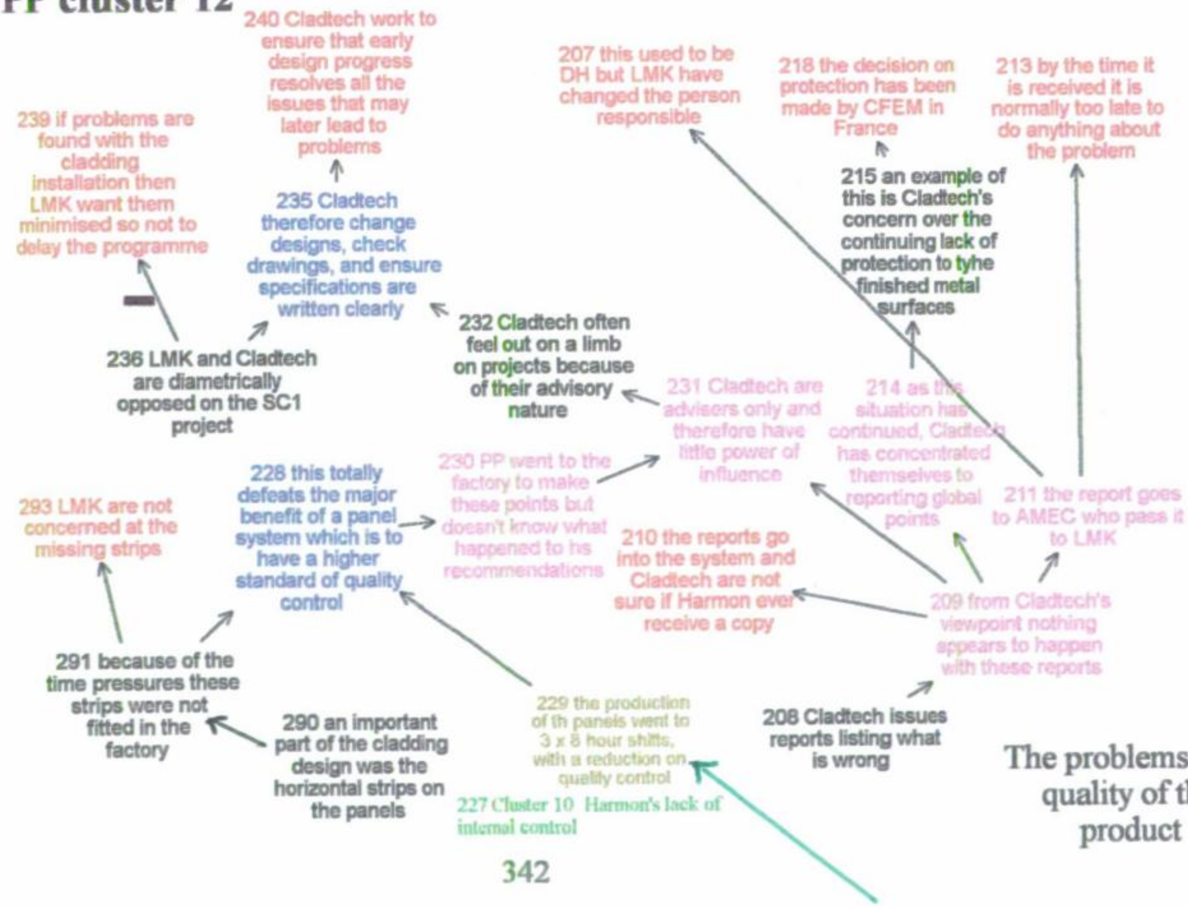
Harmon's lack of internal control

PP cluster 11



The problems with using a panelised system

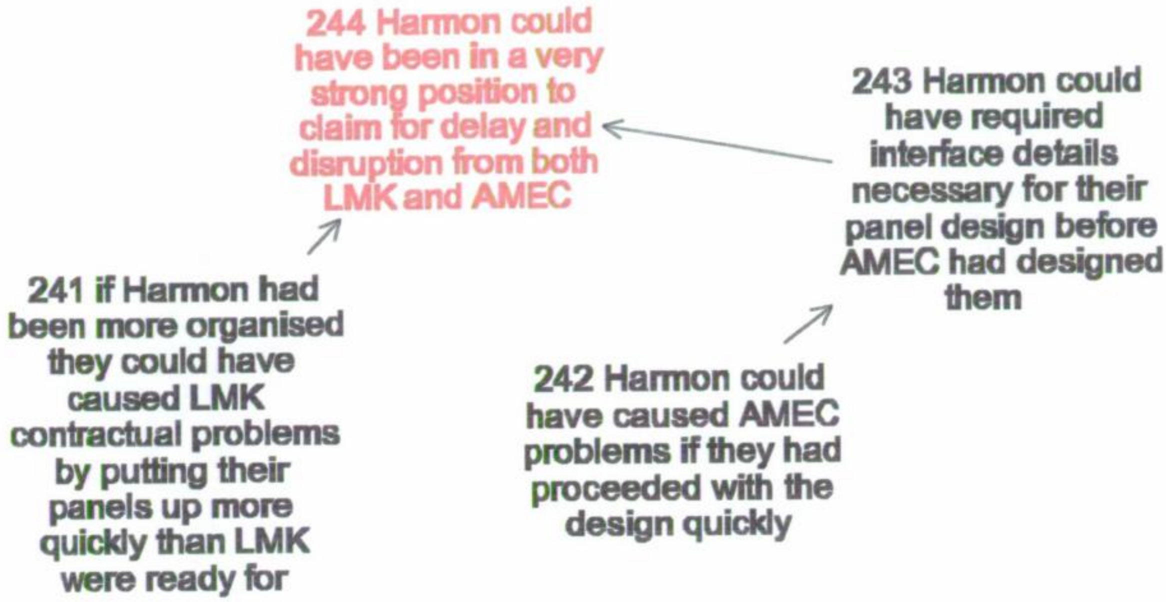
PP cluster 12



The problems with quality of the product

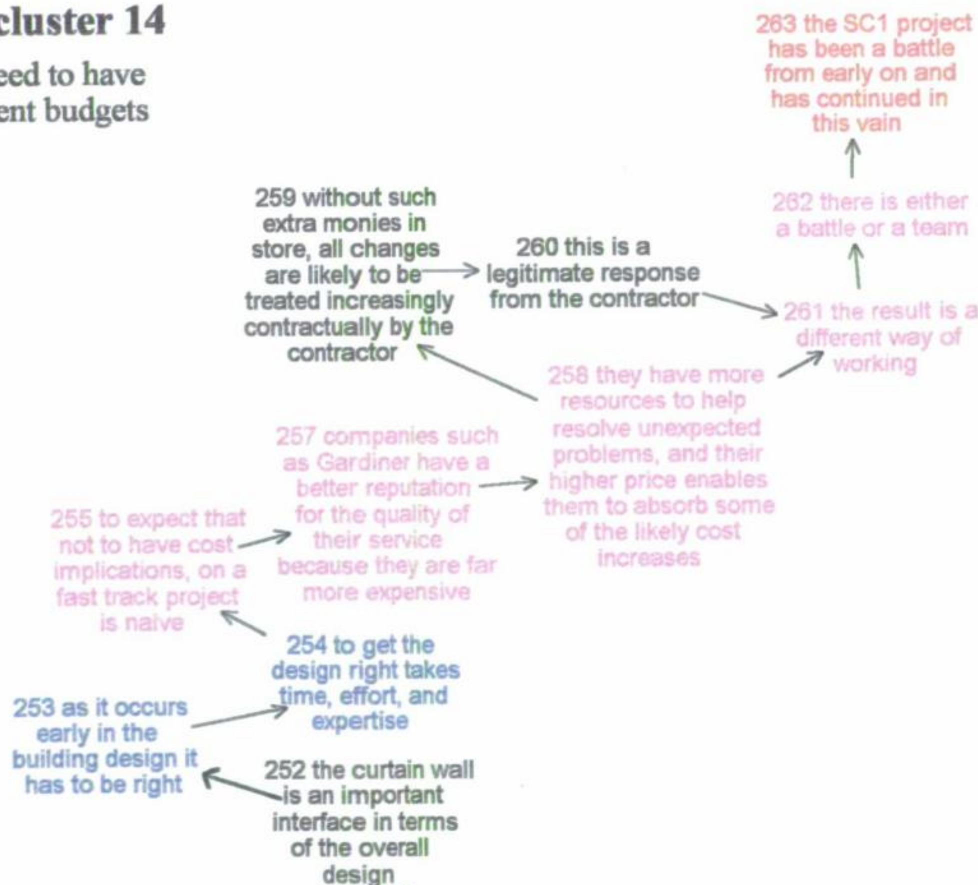
PP cluster 13

Harmon's missed opportunites



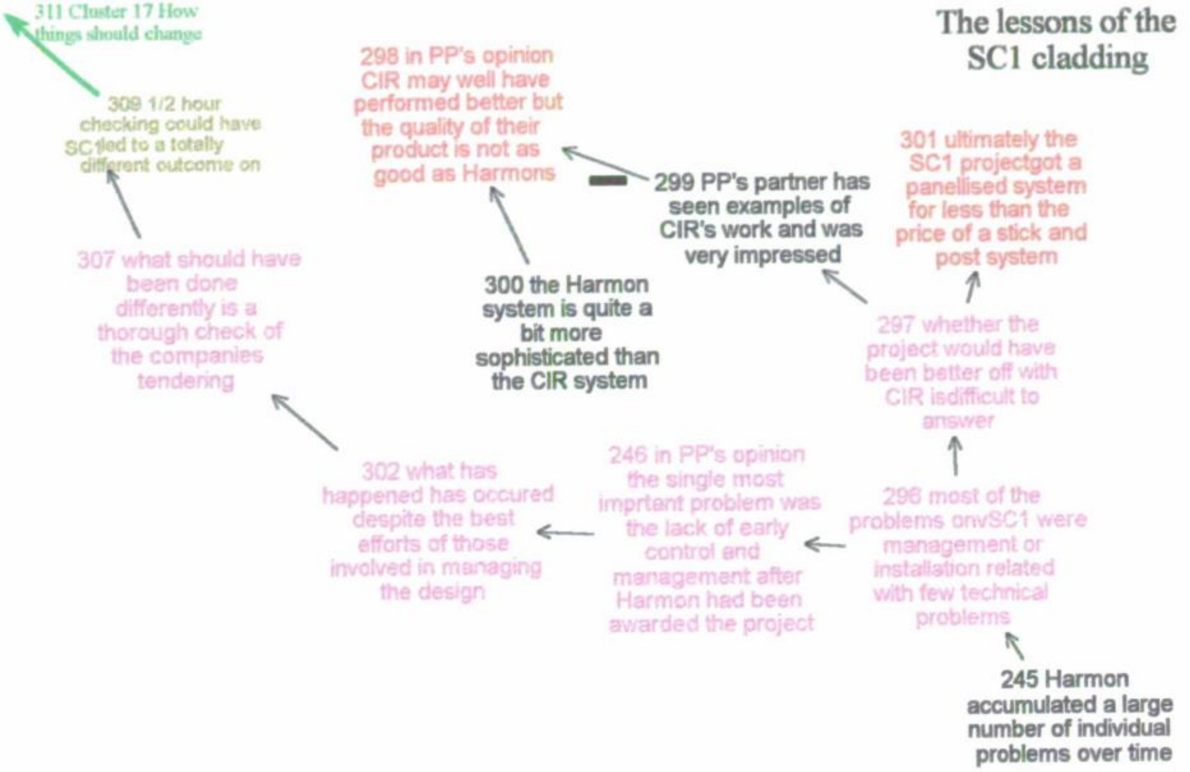
PP cluster 14

The need to have sufficient budgets



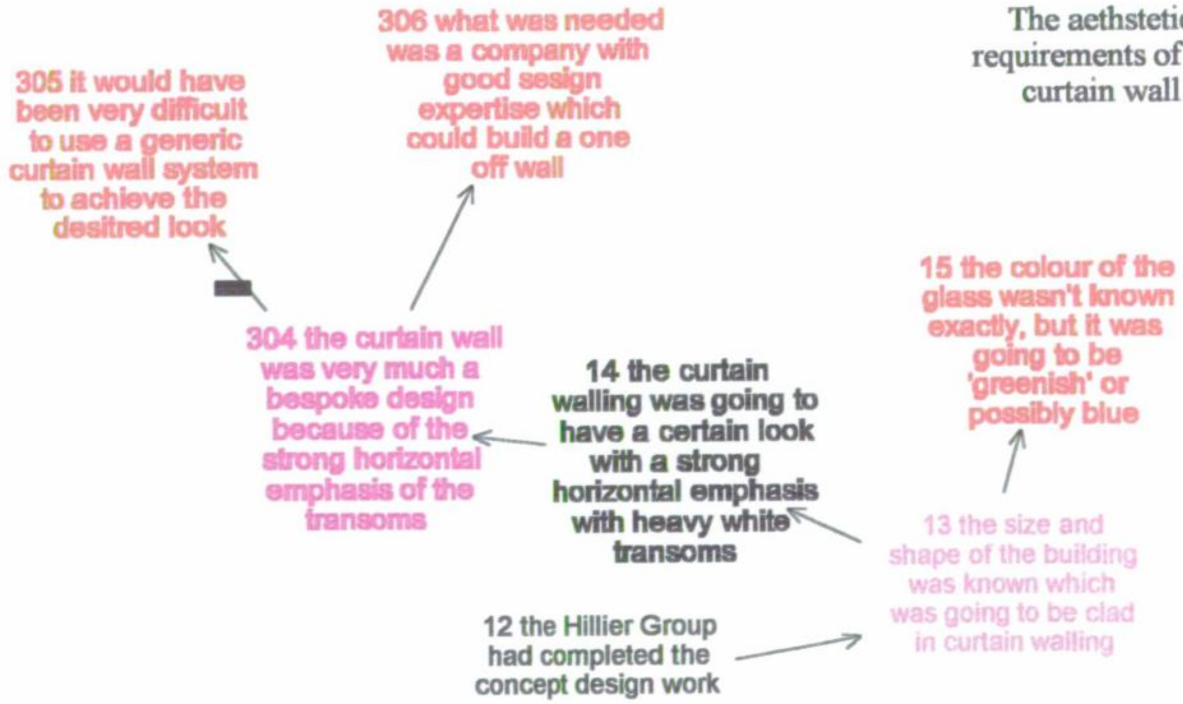
PP cluster 15

The lessons of the SC1 cladding



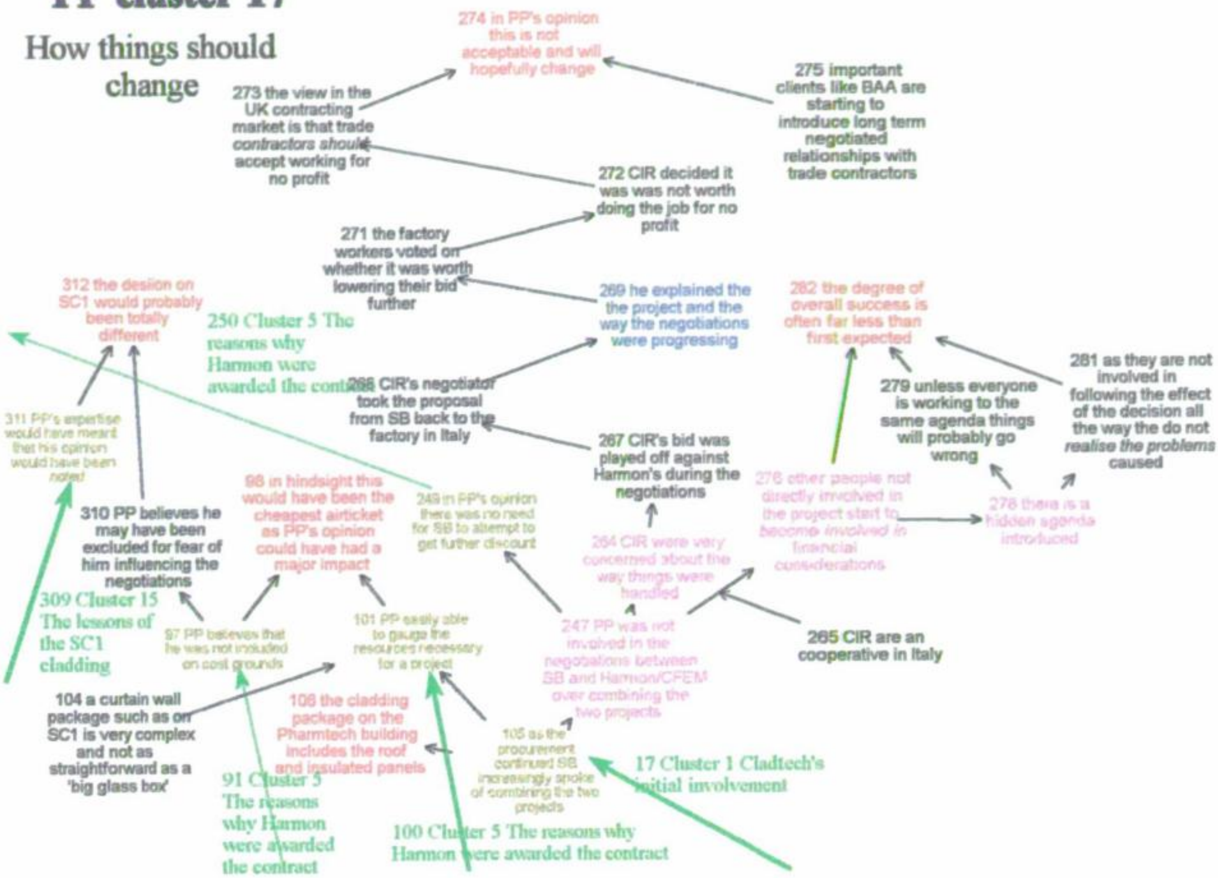
PP cluster 16

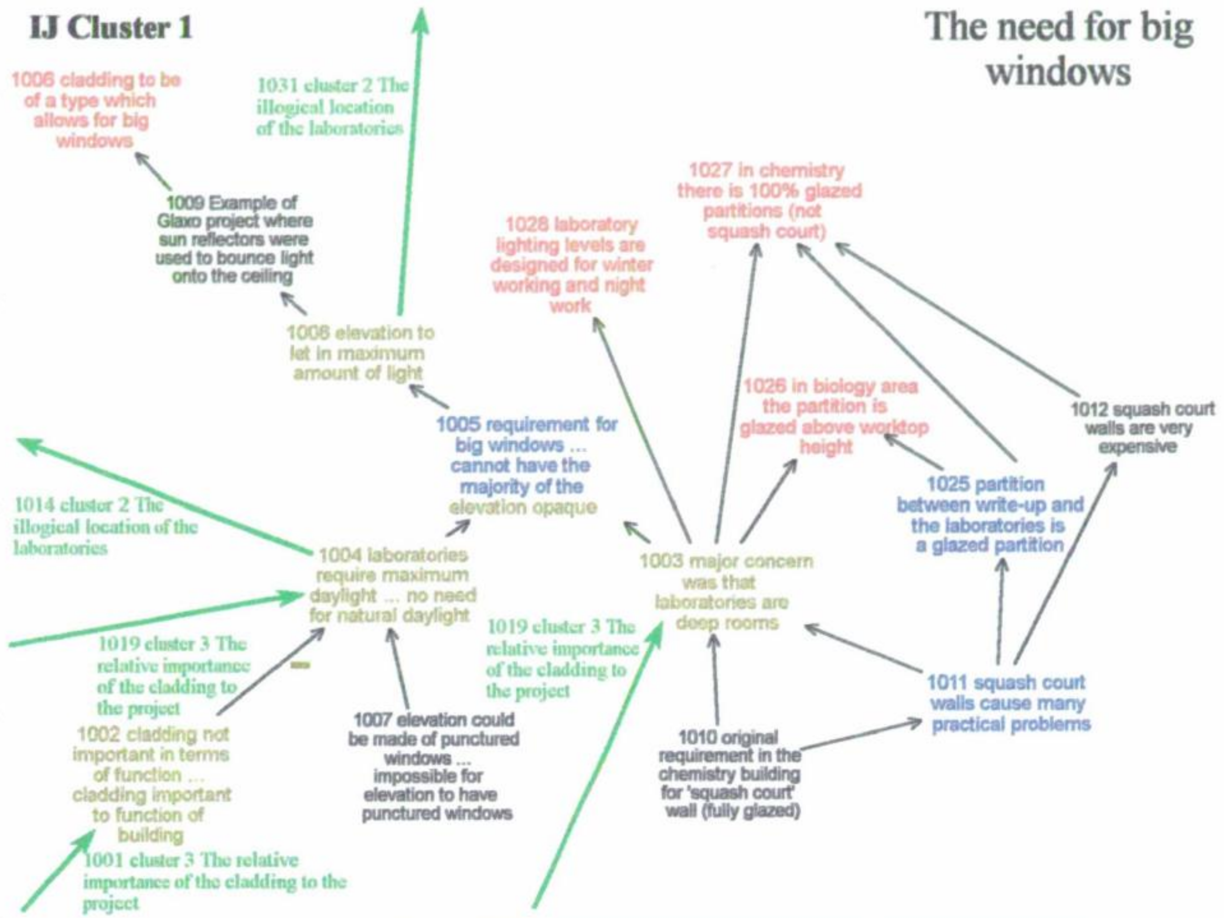
The aethstetic requirements of the curtain wall

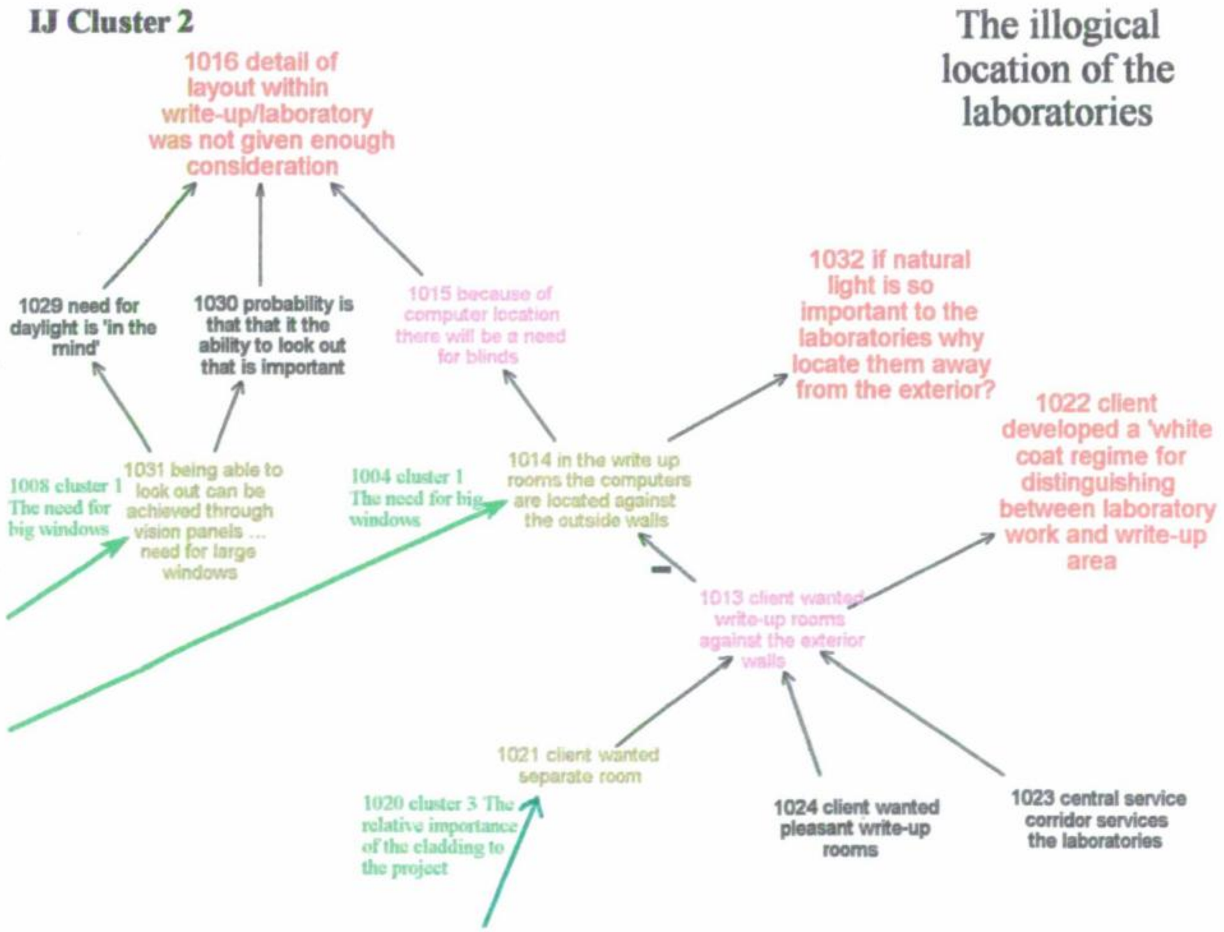


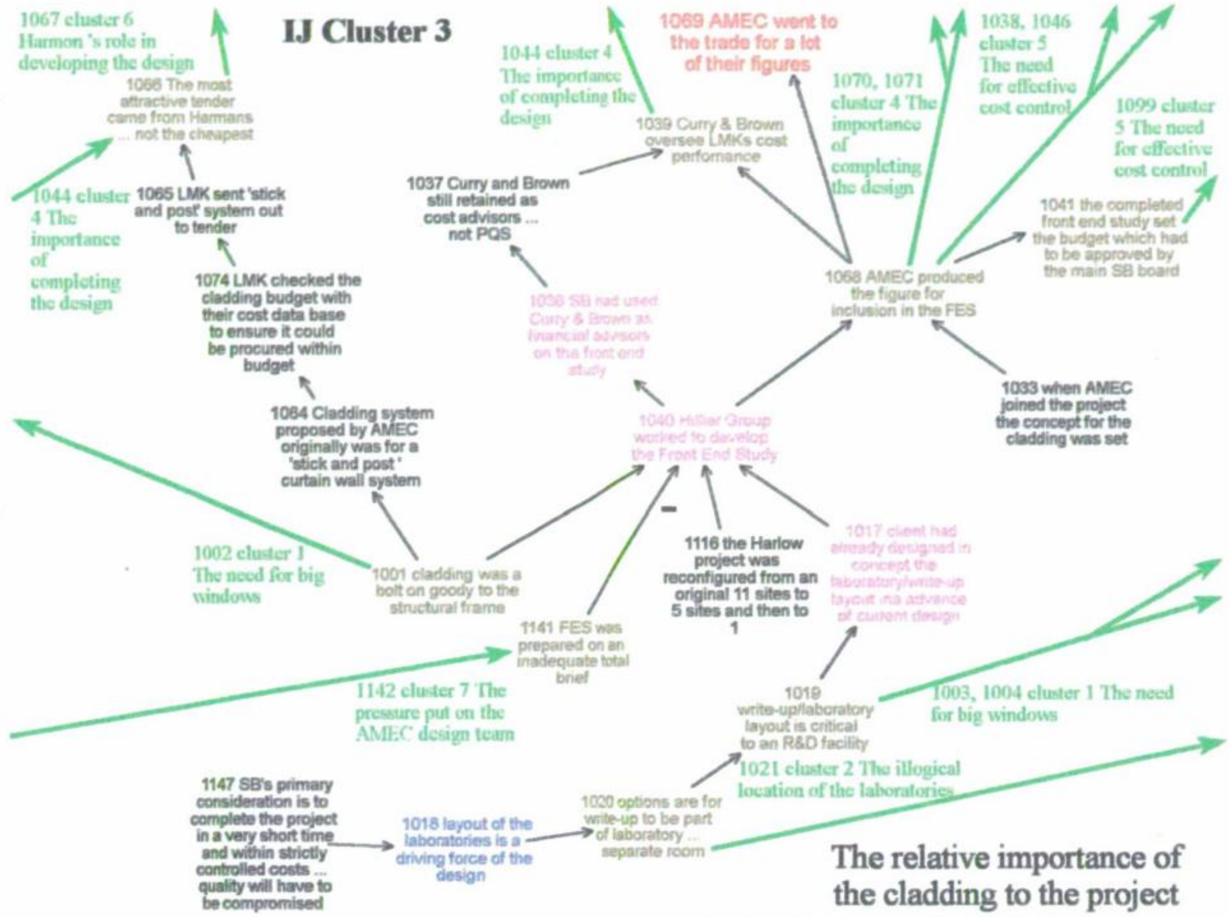
PP cluster 17

How things should change

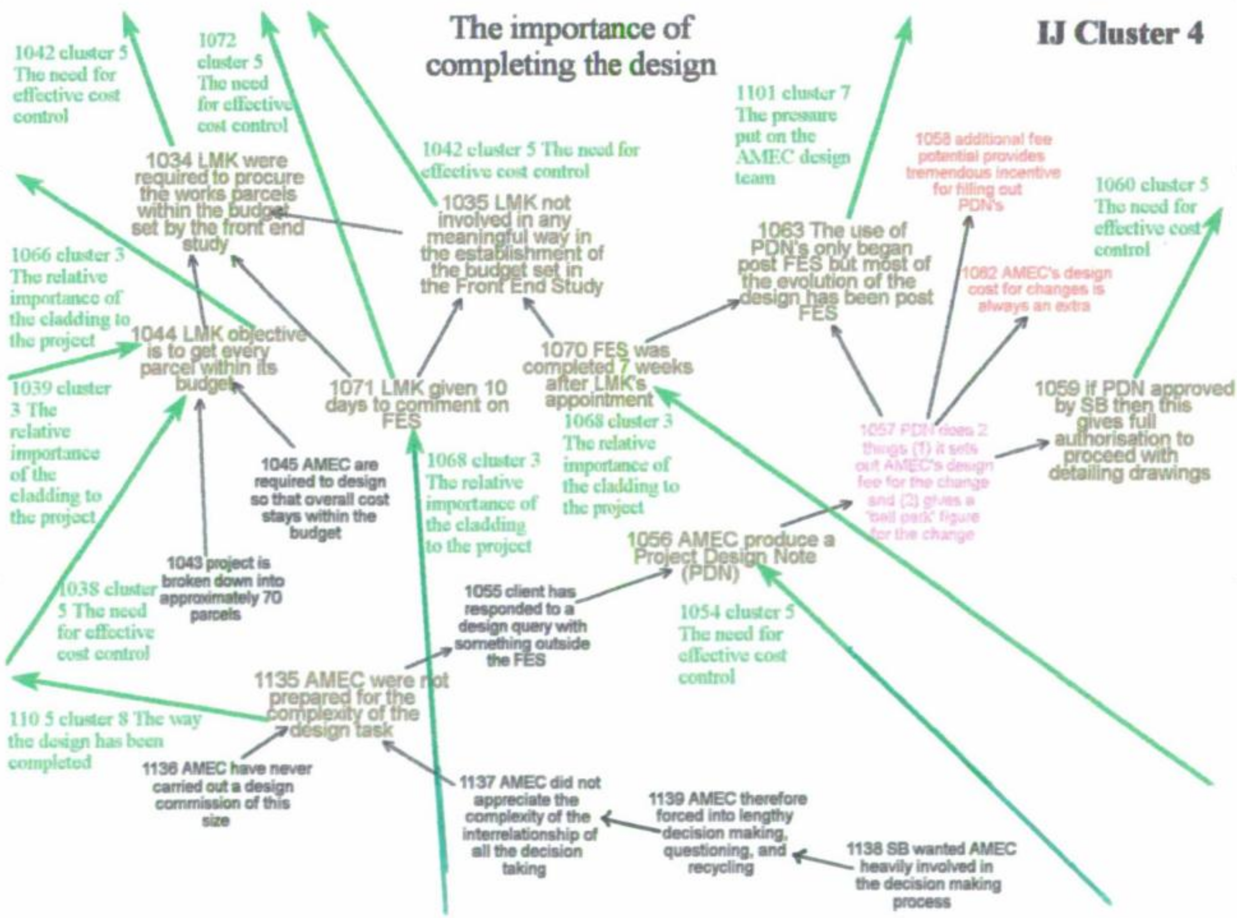



IJ Cluster 1
The need for big windows
1006 cladding to be of a type which allows for big windows
1031 cluster 2 The illogical location of the laboratories
1009 Example of Glaxo project where sun reflectors were used to bounce light onto the ceiling
1027 in chemistry there is 100% glazed partitions (not squash court)
1028 laboratory lighting levels are designed for winter working and night work
1008 elevation to let in maximum amount of light
1026 in biology area the partition is glazed above worktop height
1012 squash court walls are very expensive
1005 requirement for big windows ... cannot have the majority of the elevation opaque
1025 partition between write-up and the laboratories is a glazed partition
1014 cluster 2 The illogical location of the laboratories
1004 laboratories require maximum daylight ... no need for natural daylight
1003 major concern was that laboratories are deep rooms
1019 cluster 3 The relative importance of the cladding to the project
1019 cluster 3 The relative importance of the cladding to the project
1011 squash court walls cause many practical problems
1002 cladding not important in terms of function ... cladding important to function of building
1007 elevation could be made of punctured windows ... impossible for elevation to have punctured windows
1010 original requirement in the chemistry building for 'squash court' wall (fully glazed)
1001 cluster 3 The relative importance of the cladding to the project


IJ Cluster 2
The illogical location of the laboratories
1016 detail of layout within write-up/laboratory was not given enough consideration
1032 if natural light is so important to the laboratories why locate them away from the exterior?
1029 need for daylight is 'in the mind'
1030 probability is that that it the ability to look out that is important
1015 because of computer location there will be a need for blinds
1022 client developed a 'white coat regime for distinguishing between laboratory work and write-up area
1008 cluster 1 The need for big windows
1031 being able to look out can be achieved through vision panels ... need for large windows
1004 cluster 1 The need for big windows
1014 in the write up rooms the computers are located against the outside walls
1013 client wanted write-up rooms against the exterior walls
1021 client wanted separate room
1020 cluster 3 The relative importance of the cladding to the project
1024 client wanted pleasant write-up rooms
1023 central service corridor services the laboratories

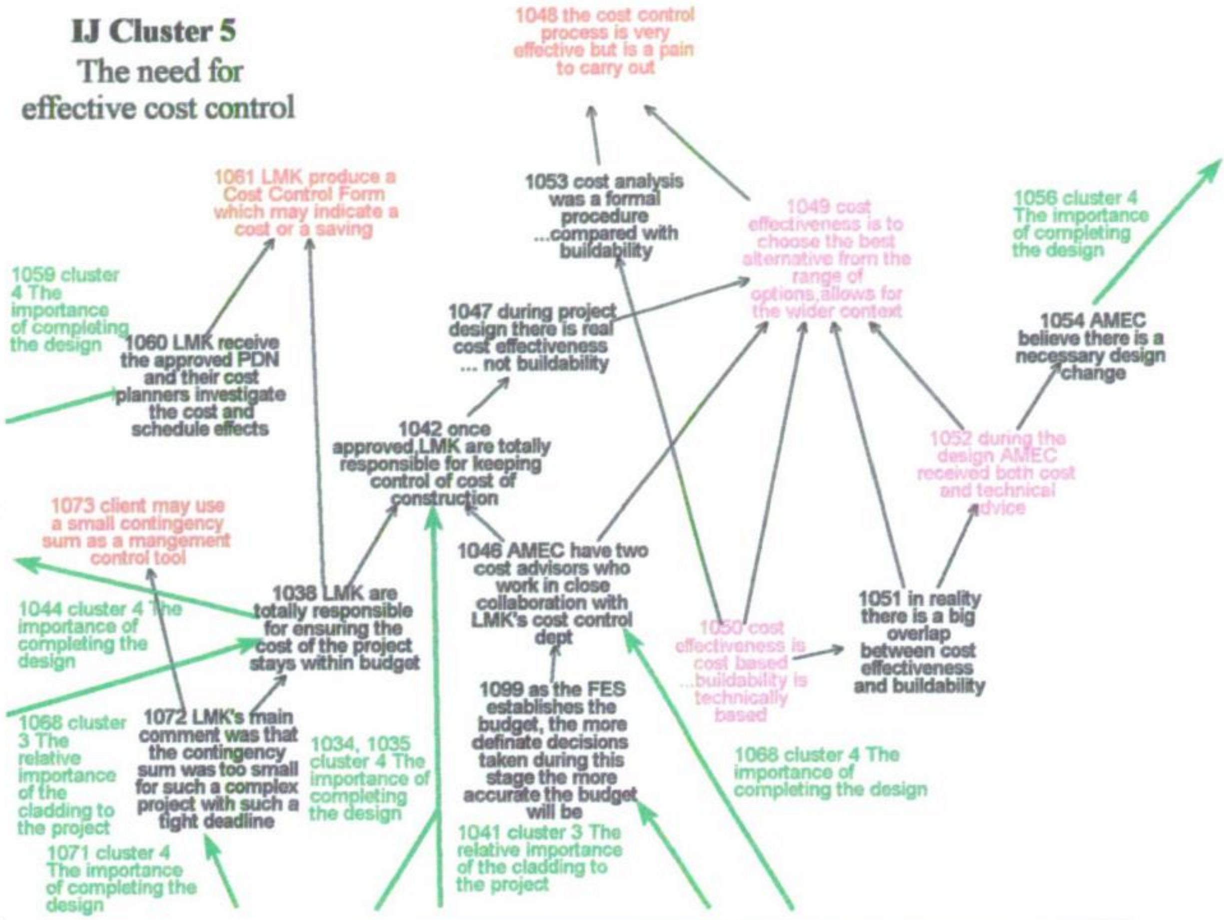


IJ Cluster 3
1067 cluster 6 Harmon 's role in developing the design
1066 The most attractive tender came from Harmans ... not the cheapest
1044 cluster 4 The importance of completing the design
1065 LMK sent 'stick and post' system out to tender
1074 LMK checked the cladding budget with their cost data base to ensure it could be procured within budget
1064 Cladding system proposed by AMEC originally was for a 'stick and post' curtain wall system
1044 cluster 4 The importance of completing the design
1037 Curry and Brown still retained as cost advisors ... not PQS
1039 Curry & Brown oversee LMKs cost performance
1069 AMEC went to the trade for a lot of their figures
1070, 1071 cluster 4 The importance of completing the design
1038, 1046 cluster 5 The need for effective cost control
1099 cluster 5 The need for effective cost control
1041 the completed front end study set the budget which had to be approved by the main SB board
1068 AMEC produced the figure for inclusion in the FES
1036 SB had used Curry & Brown as financial advisors on the front end study
1040 Hillier Group worked to develop the Front End Study
1033 when AMEC joined the project the concept for the cladding was set
1002 cluster 1 The need for big windows
1001 cladding was a bolt on goody to the structural frame
1116 the Harlow project was reconfigured from an original 11 sites to 5 sites and then to 1
1017 client had already designed in concept the laboratory/write-up layout ina advance of current design
1141 FES was prepared on an inadequate total brief
1142 cluster 7 The pressure put on the AMEC design team
1019 write-up/laboratory layout is critical to an R&D facility
1003, 1004 cluster 1 The need for big windows
1021 cluster 2 The illogical location of the laboratories
1147 SB's primary consideration is to complete the project in a very short time and within strictly controlled costs ... quality will have to be compromised
1018 layout of the laboratories is a driving force of the design
1020 options are for write-up to be part of laboratory ... separate room
The relative importance of the cladding to the project

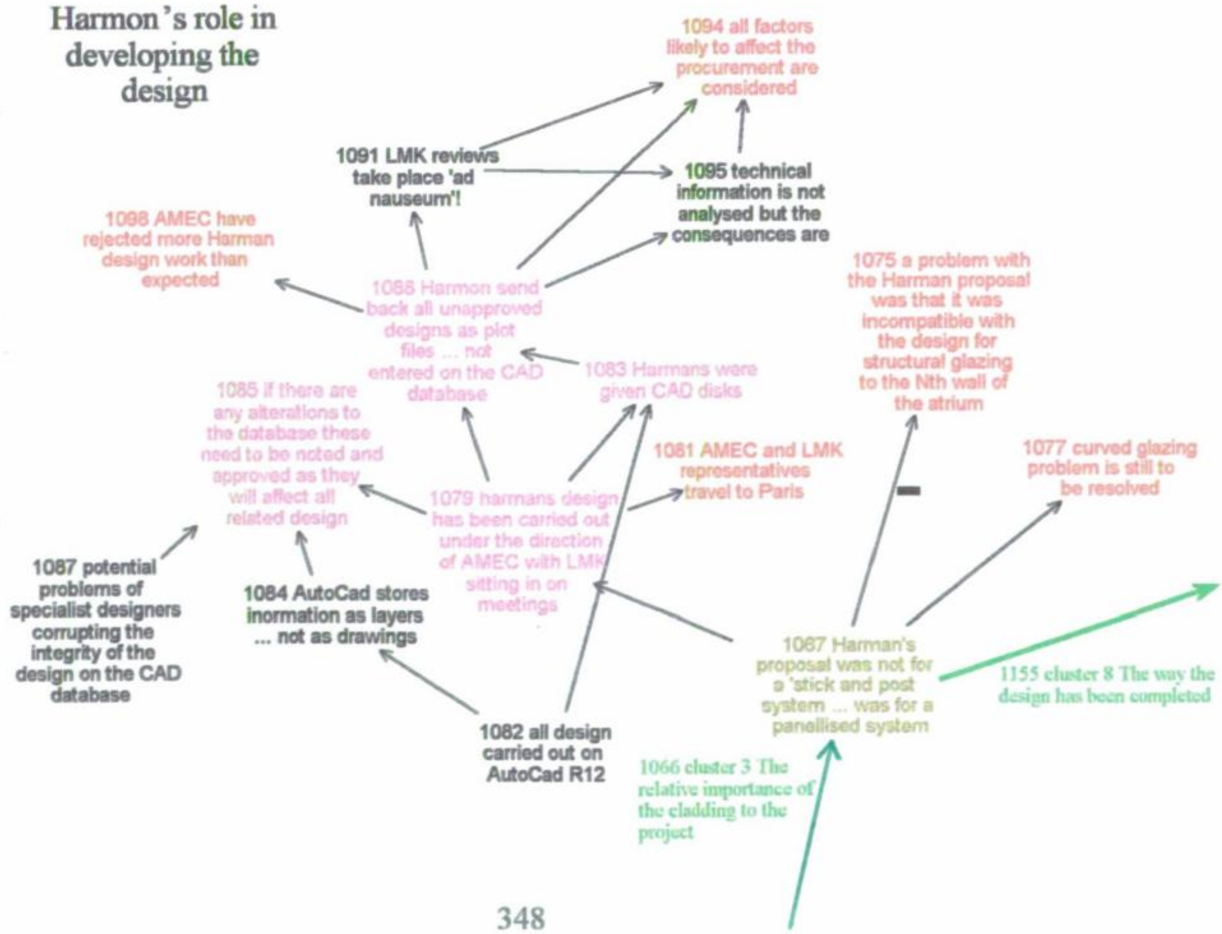


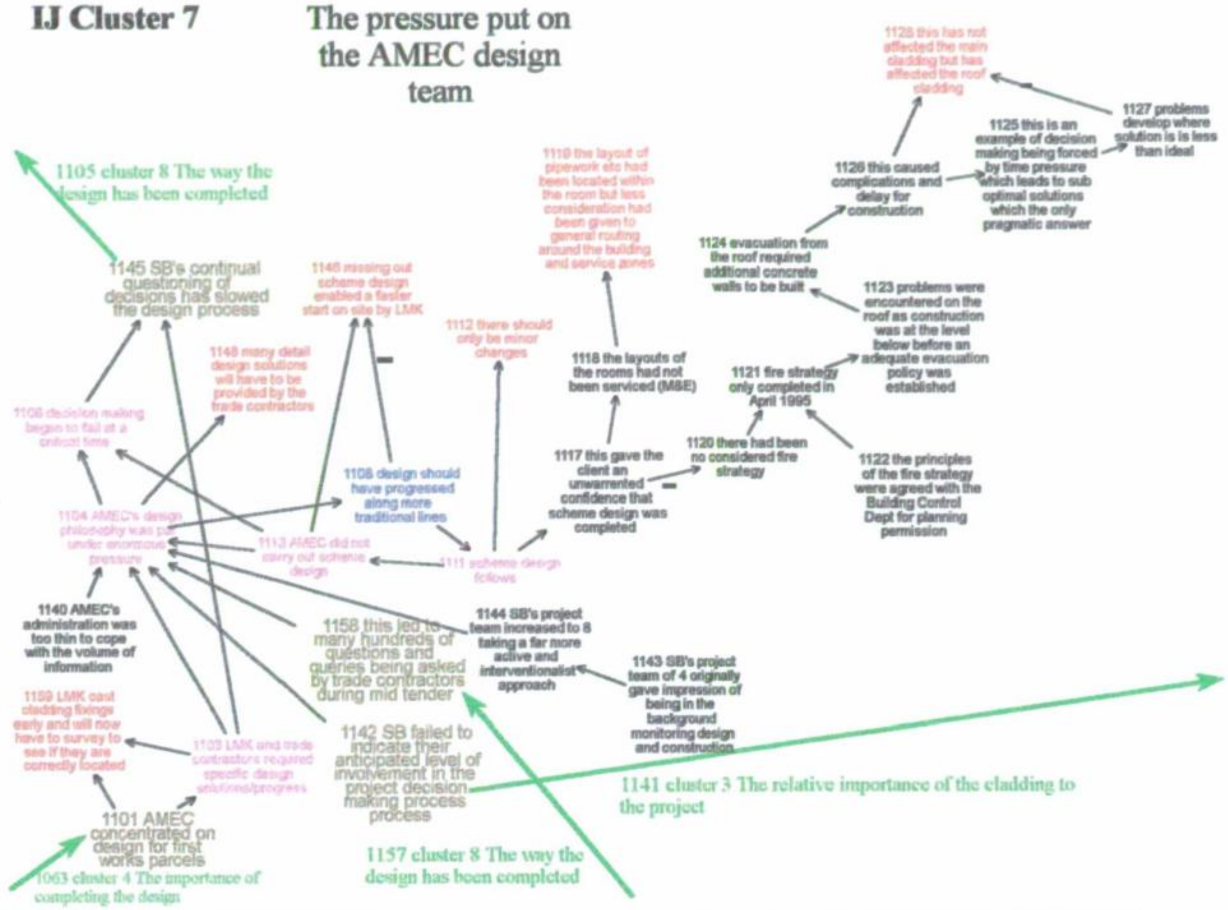
The importance of completing the design
IJ Cluster 4
1042 cluster 5 The need for effective cost control
1072 cluster 5 The need for effective cost control
1042 cluster 5 The need for effective cost control
1101 cluster 7 The pressure put on the AMEC design team
1058 additional fee potential provides tremendous incentive for filling out PDN's
1060 cluster 5 The need for effective cost control
1034 LMK were required to procure the works parcels within the budget set by the front end study
1035 LMK not involved in any meaningful way in the establishment of the budget set in the Front End Study
1063 The use of PDN's only began post FES but most of the evolution of the design has been post FES
1062 AMEC's design cost for changes is always an extra
1066 cluster 3 The relative importance of the cladding to the project
1044 LMK objective is to get every parcel within its budget
1039 cluster 3 The relative importance of the cladding to the project
1071 LMK given 10 days to comment on FES
1070 FES was completed 7 weeks after LMK's appointment
1068 cluster 3 The relative importance of the cladding to the project
1059 if PDN approved by SB then this gives full authorisation to proceed with detailing drawings
1057 PDN does 2 things (1) it sets out AMEC's design fee for the change and (2) gives a 'ball park' figure for the change
1045 AMEC are required to design so that overall cost stays within the budget
1068 cluster 3 The relative importance of the cladding to the project
1056 AMEC produce a Project Design Note (PDN)
1043 project is broken down into approximately 70 parcels
1038 cluster 5 The need for effective cost control
1055 client has responded to a design query with something outside the FES
1054 cluster 5 The need for effective cost control
1135 AMEC were not prepared for the complexity of the design task
110 5 cluster 8 The way the design has been completed
1136 AMEC have never carried out a design commission of this size
1137 AMEC did not appreciate the complexity of the interrelationship of all the decision taking
1139 AMEC therefore forced into lengthy decision making, questioning, and recycling
1138 SB wanted AMEC heavily involved in the decision making process

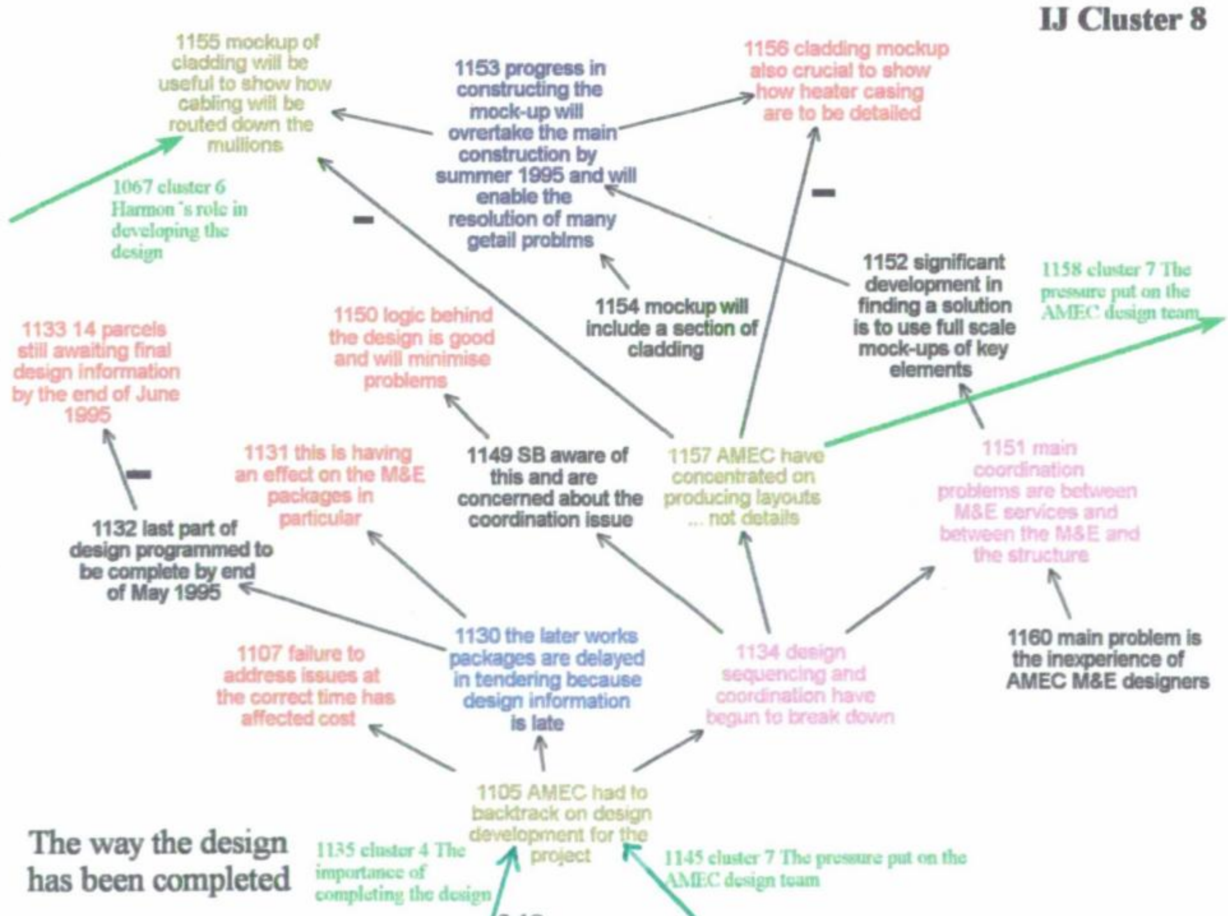
IJ Cluster 5
The need for effective cost control



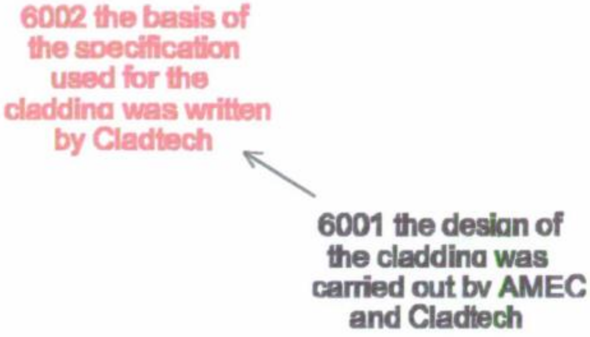
IJ Cluster 6
Harmon's role in developing the design



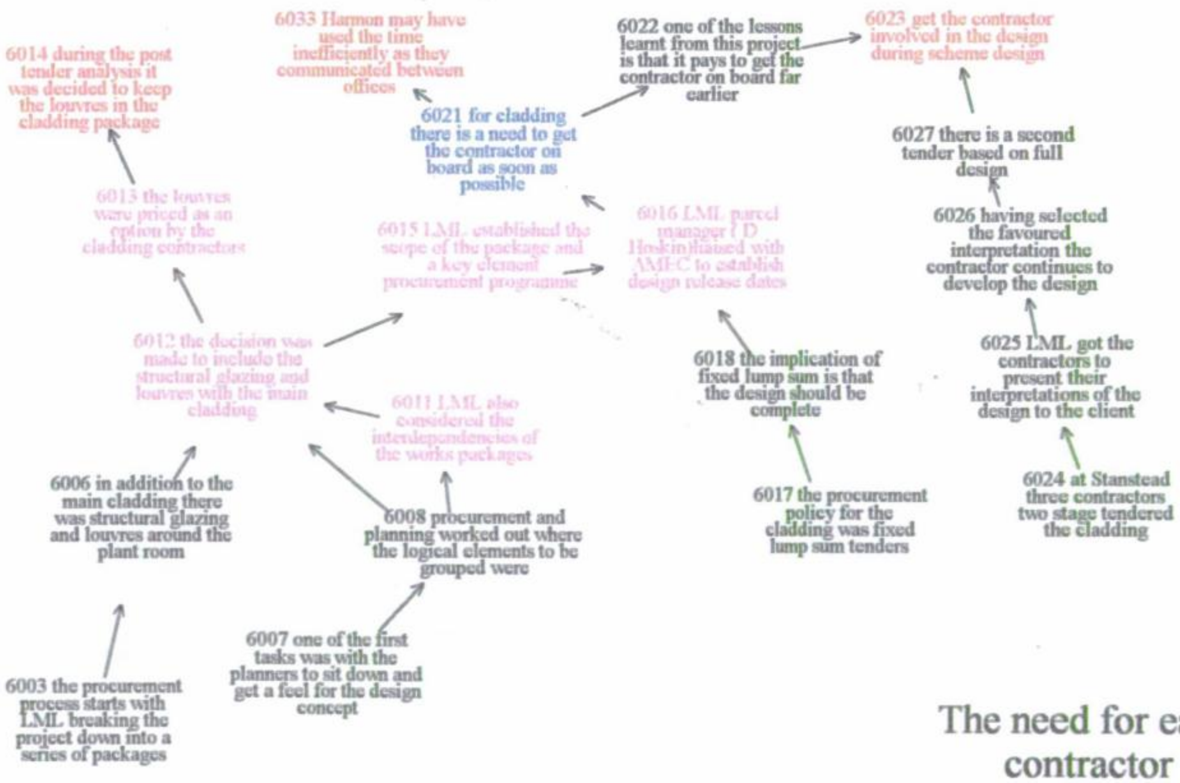

IJ Cluster 7
The pressure put on the AMEC design team
1105 cluster 8 The way the design has been completed
1145 SB's continual questioning of decisions has slowed the design process
1146 missing out scheme design enabled a faster start on site by LMK
1119 the layout of pipework etc had been located within the room but less consideration had been given to general routing around the building and service zones
1128 this has not affected the main cladding but has affected the roof cladding
1127 problems develop where solution is is less than ideal
1125 this is an example of decision making being forced by time pressure which leads to sub optimal solutions which the only pragmatic answer
1126 this caused complications and delay for construction
1124 evacuation from the roof required additional concrete walls to be built
1123 problems were encountered on the roof as construction was at the level below before an adequate evacuation policy was established
1112 there should only be minor changes
1148 many detail design solutions will have to be provided by the trade contractors
1118 the layouts of the rooms had not been serviced (M&E)
1121 fire strategy only completed in April 1995
1106 decision making began to fail at a critical time
1120 there had been no considered fire strategy
1122 the principles of the fire strategy were agreed with the Building Control Dept for planning permission
1117 this gave the client an unwarrented confidence that scheme design was completed
1108 design should have progressed along more traditional lines
1104 AMEC's design philosophy was put under enormous pressure
1113 AMEC did not carry out scheme design
1111 scheme design follows
1140 AMEC's administration was too thin to cope with the volume of information
1158 this led to many hundreds of questions and queries being asked by trade contractors during mid tender
1144 SB's project team increased to 8 taking a far more active and interventionalist approach
1143 SB's project team of 4 originally gave impression of being in the background monitoring design and construction
1159 LMK cast cladding fixings early and will now have to survey to see if they are correctly located
1103 LMK and trade contractors required specific design solutions/progress
1142 SB failed to indicate their anticipated level of involvement in the project decision making process process
1141 cluster 3 The relative importance of the cladding to the project
1101 AMEC concentrated on design for first works parcels
1063 cluster 4 The importance of completing the design
1157 cluster 8 The way the design has been completed


IJ Cluster 8
1155 mockup of cladding will be useful to show how cabling will be routed down the mullions
1153 progress in constructing the mock-up will ovrertake the main construction by summer 1995 and will enable the resolution of many getail problms
1156 cladding mockup also crucial to show how heater casing are to be detailed
1067 cluster 6 Harmon 's role in developing the design
1152 significant development in finding a solution is to use full scale mock-ups of key elements
1154 mockup will include a section of cladding
1158 cluster 7 The pressure put on the AMEC design team
1133 14 parcels still awaiting final design information by the end of June 1995
1150 logic behind the design is good and will minimise problems
1131 this is having an effect on the M&E packages in particular
1149 SB aware of this and are concerned about the coordination issue
1157 AMEC have concentrated on producing layouts ... not details
1151 main coordination problems are between M&E services and between the M&E and the structure
1132 last part of design programmed to be complete by end of May 1995
1130 the later works packages are delayed in tendering because design information is late
1134 design sequencing and coordination have begun to break down
1160 main problem is the inexperience of AMEC M&E designers
1107 failure to address issues at the correct time has affected cost
1105 AMEC had to backtrack on design development for the project
The way the design has been completed
1135 cluster 4 The importance of completing the design
1145 cluster 7 The pressure put on the AMEC design team

MW Cluster 1
The basis of the specification



MW Cluster 2

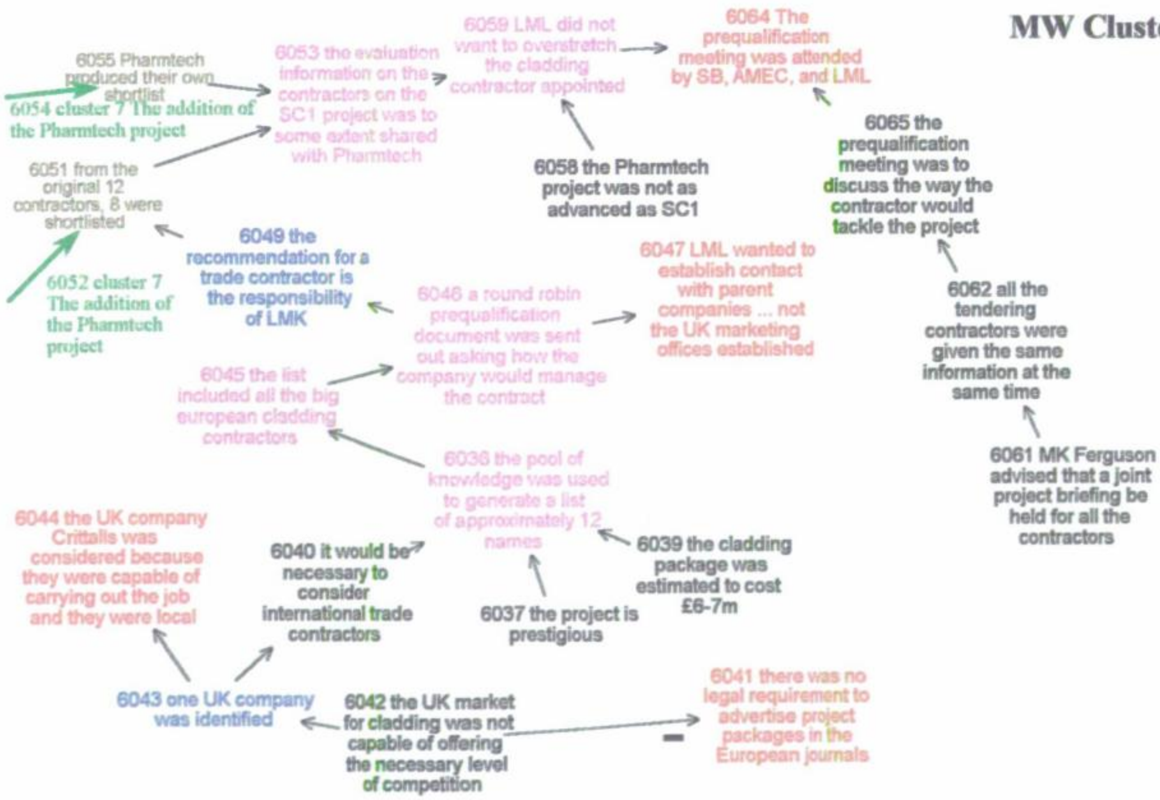


The need for early contractor involvement

MW Cluster 3

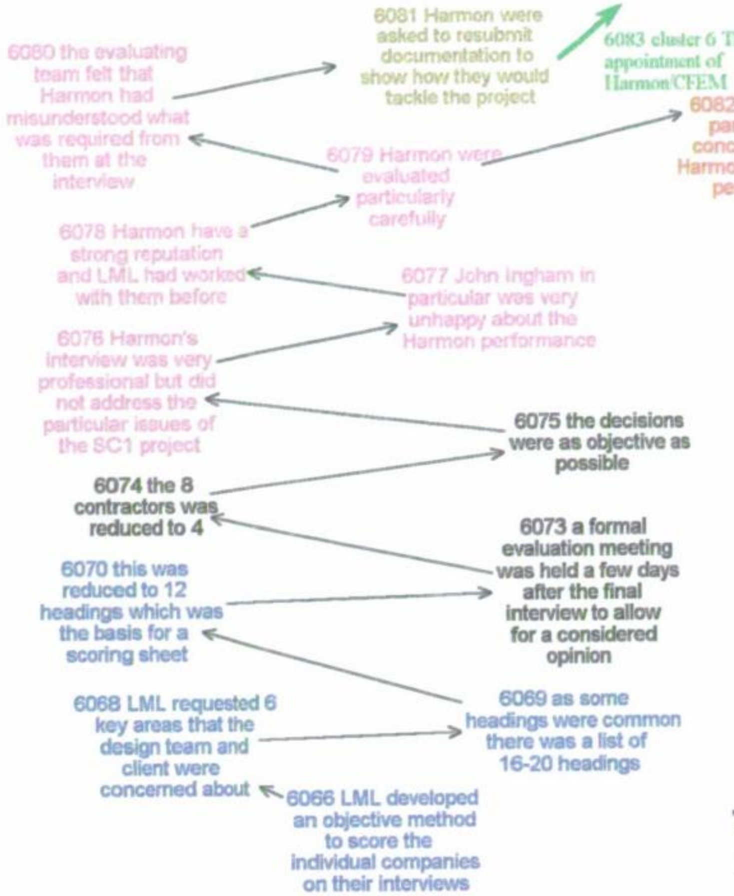
The benefits of strategic involvement of the trade contractor

MW Cluster 4



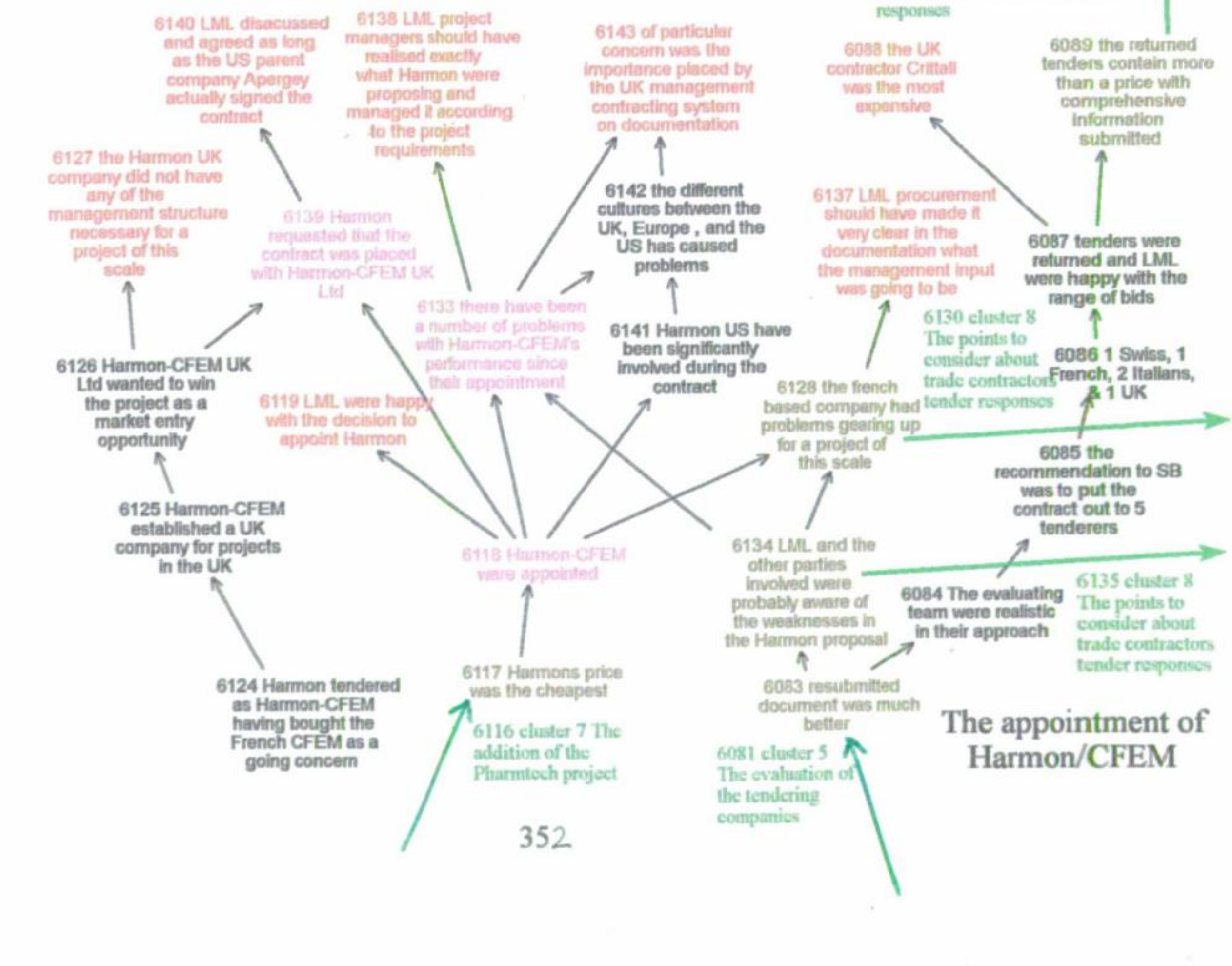
The requirements for prequalification

MW Cluster 5



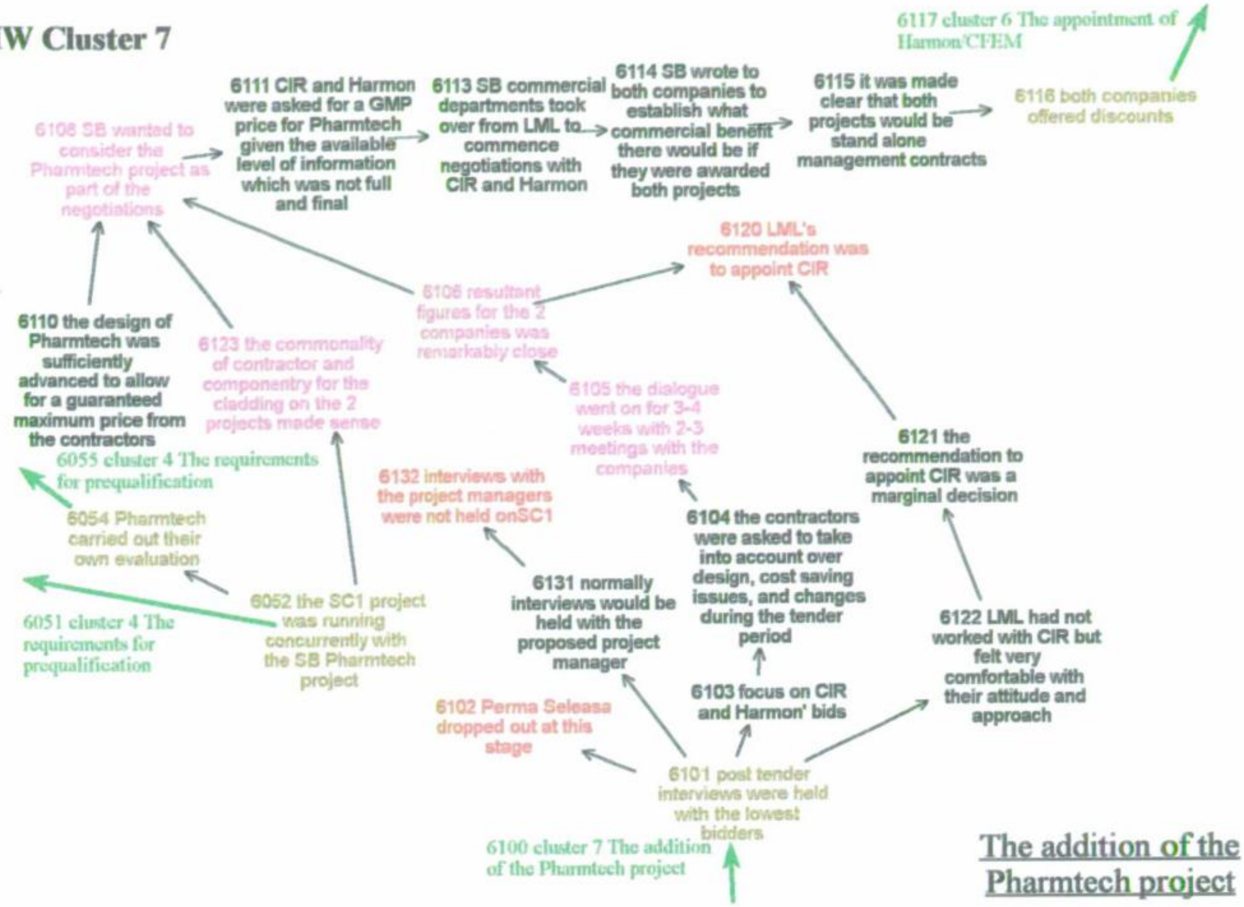
The evaluation of the tendering companies

MW Cluster 6

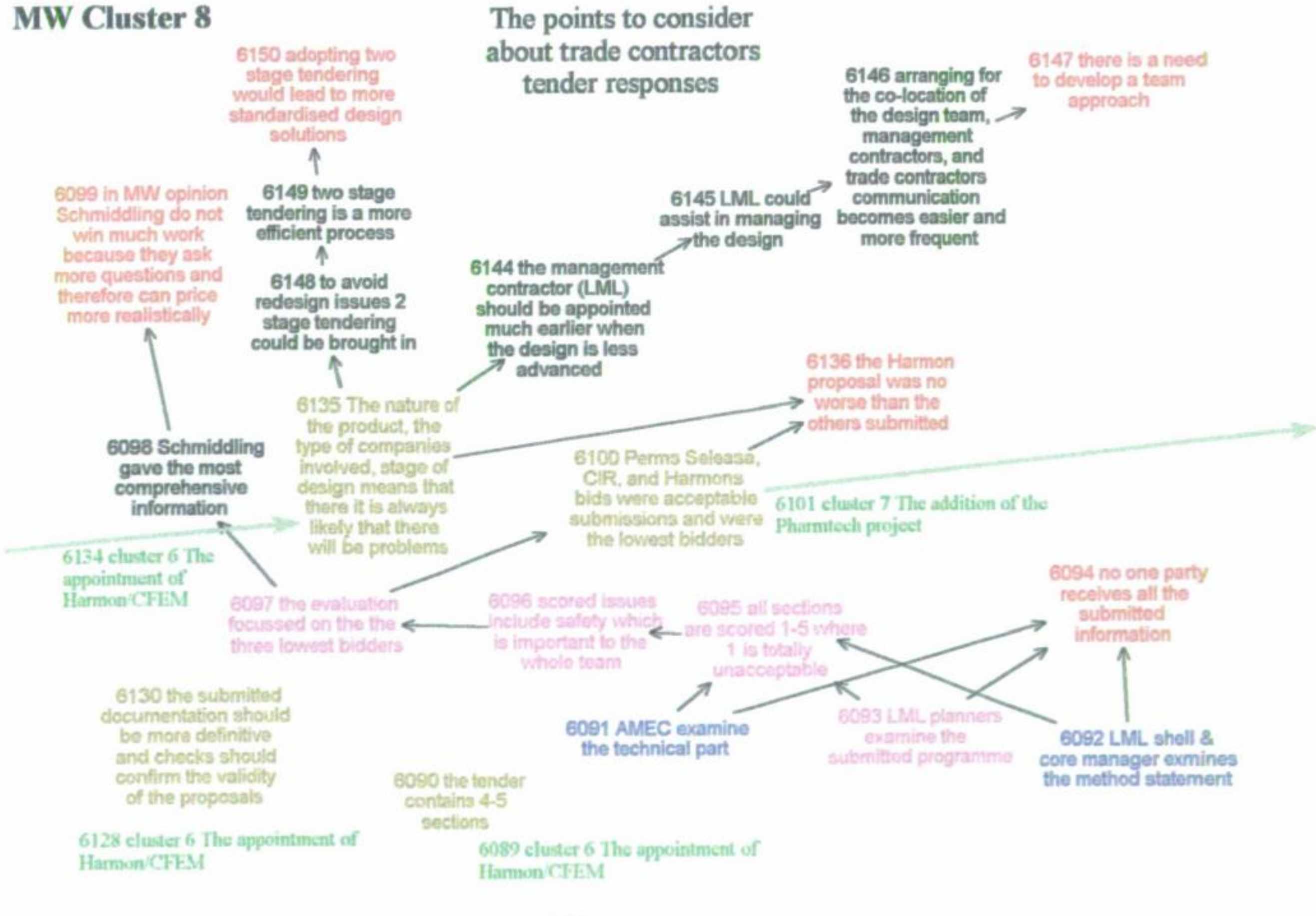


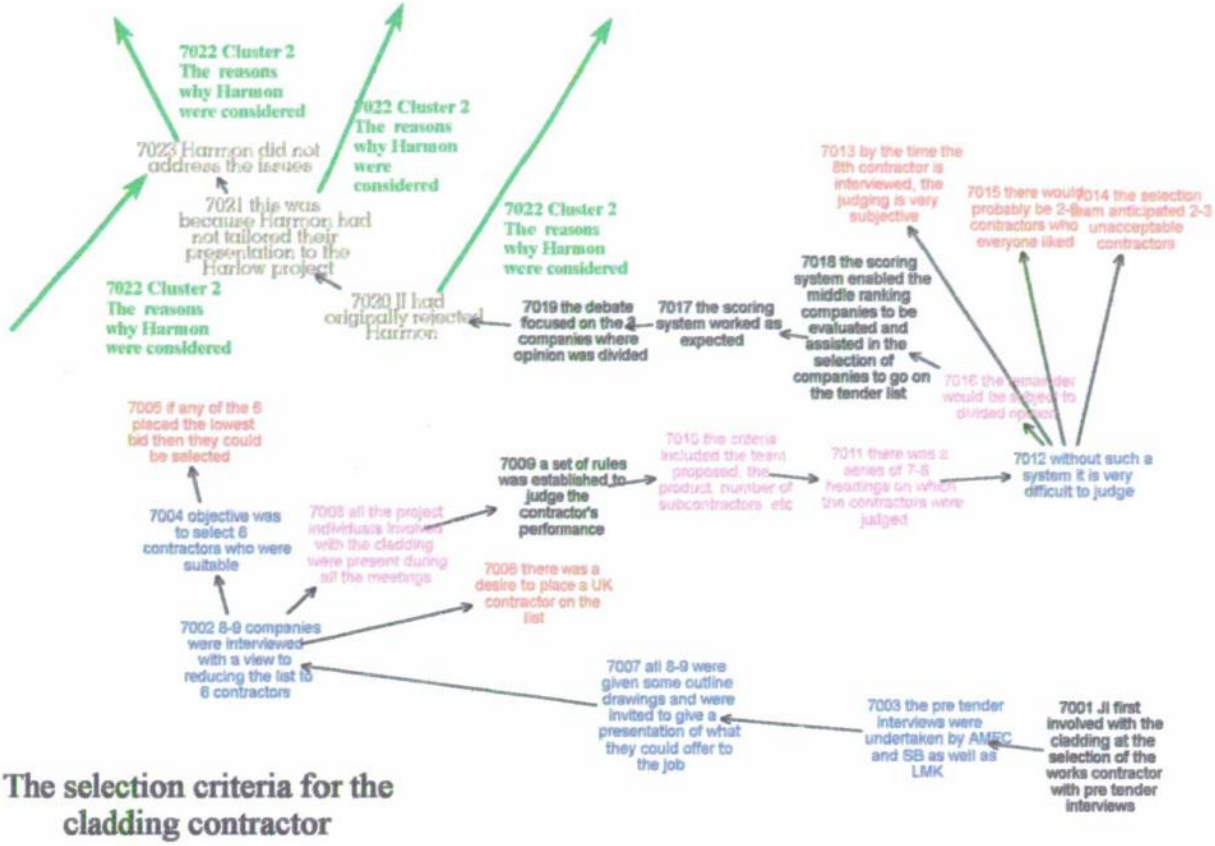
The appointment of Harmon/CFEM

MW Cluster 7



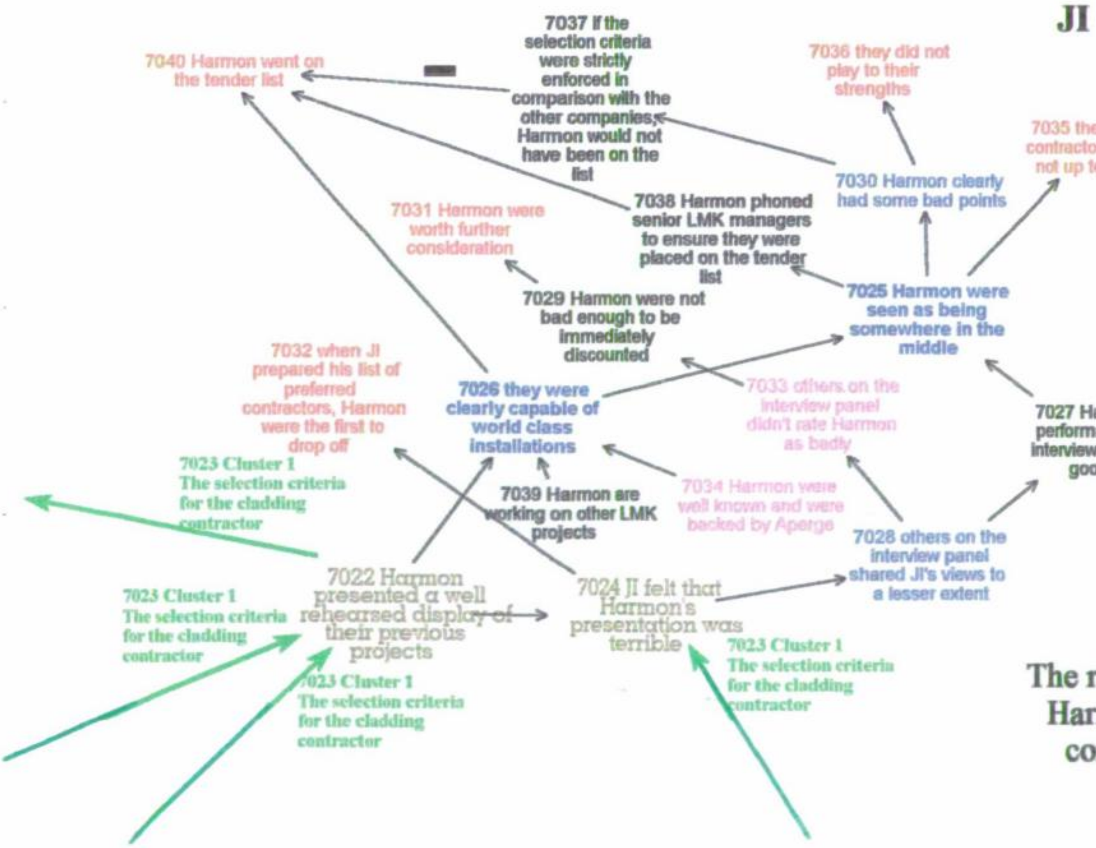
MW Cluster 8





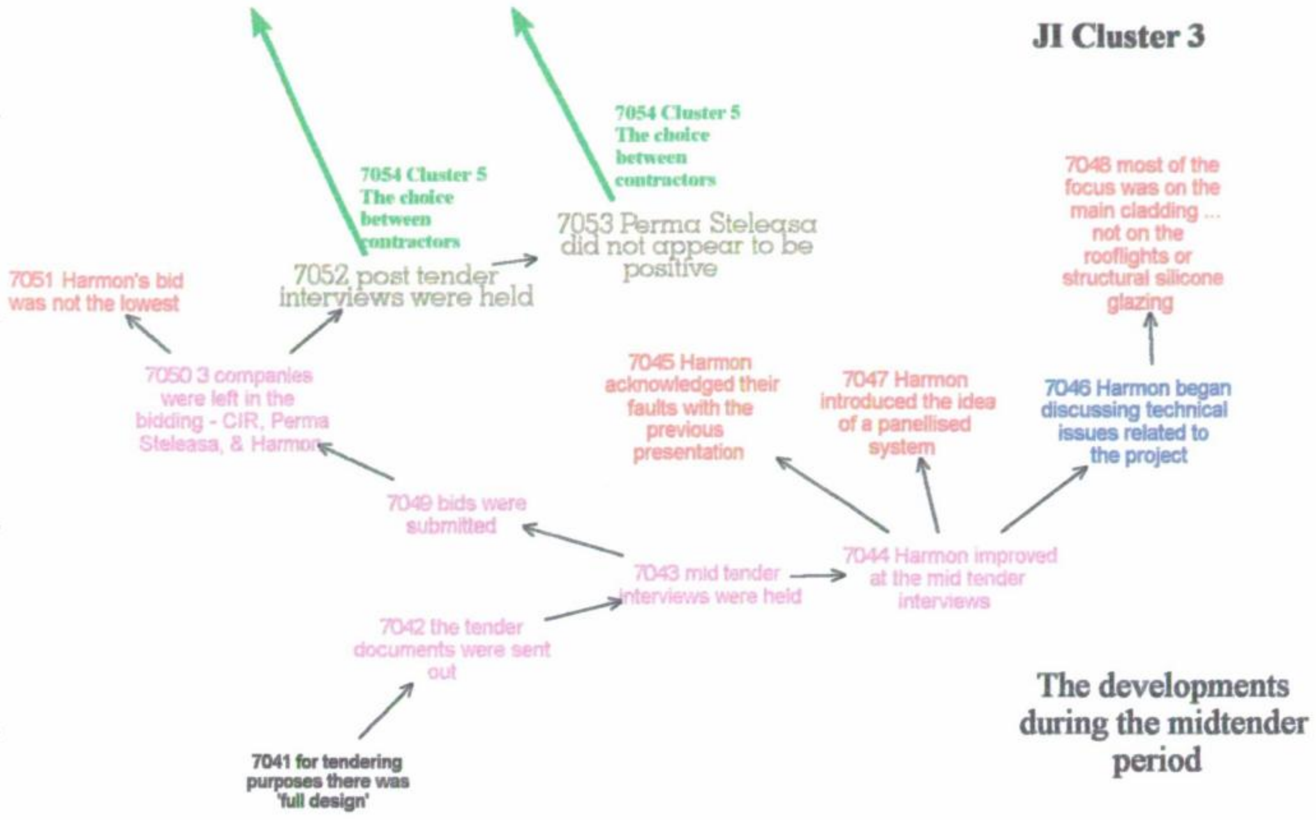
The selection criteria for the cladding contractor

JI Cluster 2



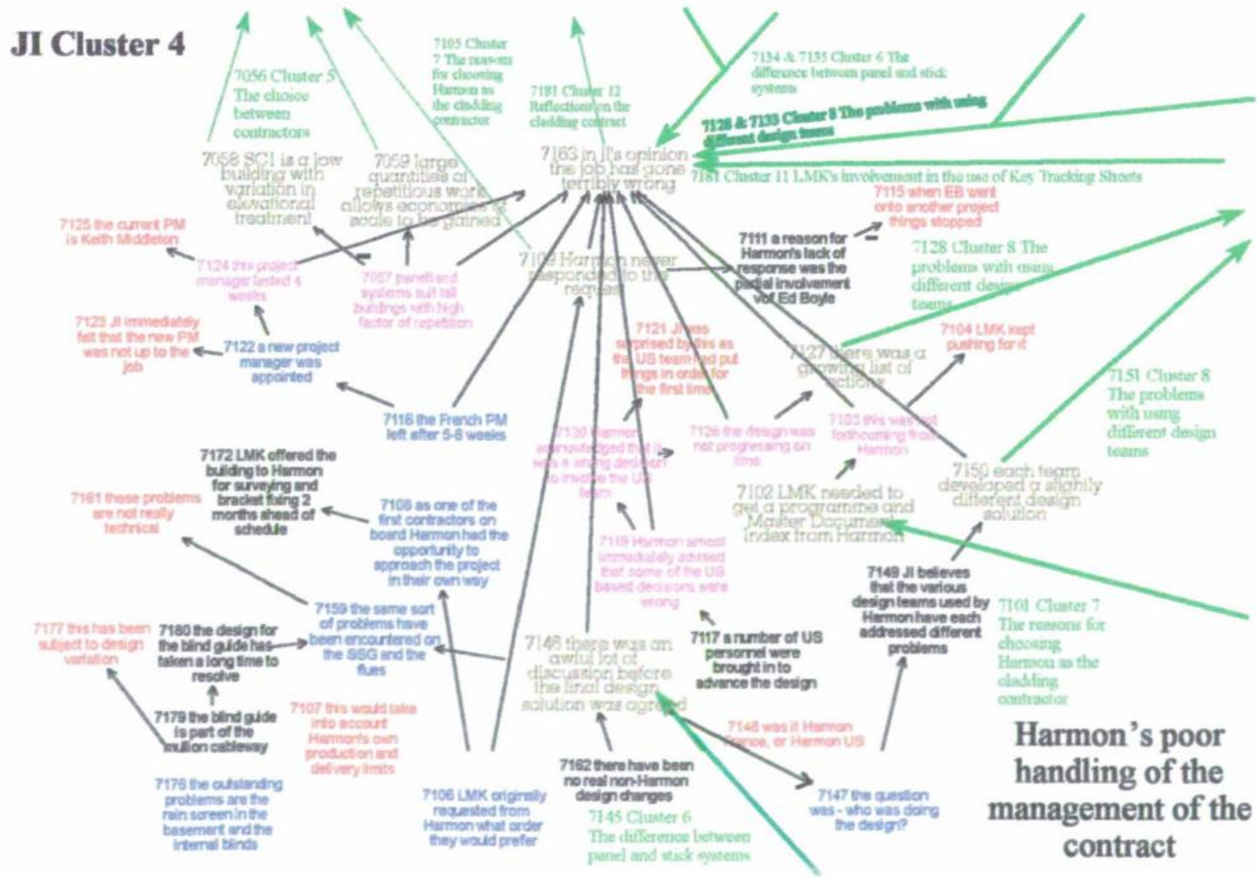
The reasons why Harmon were considered

JI Cluster 3

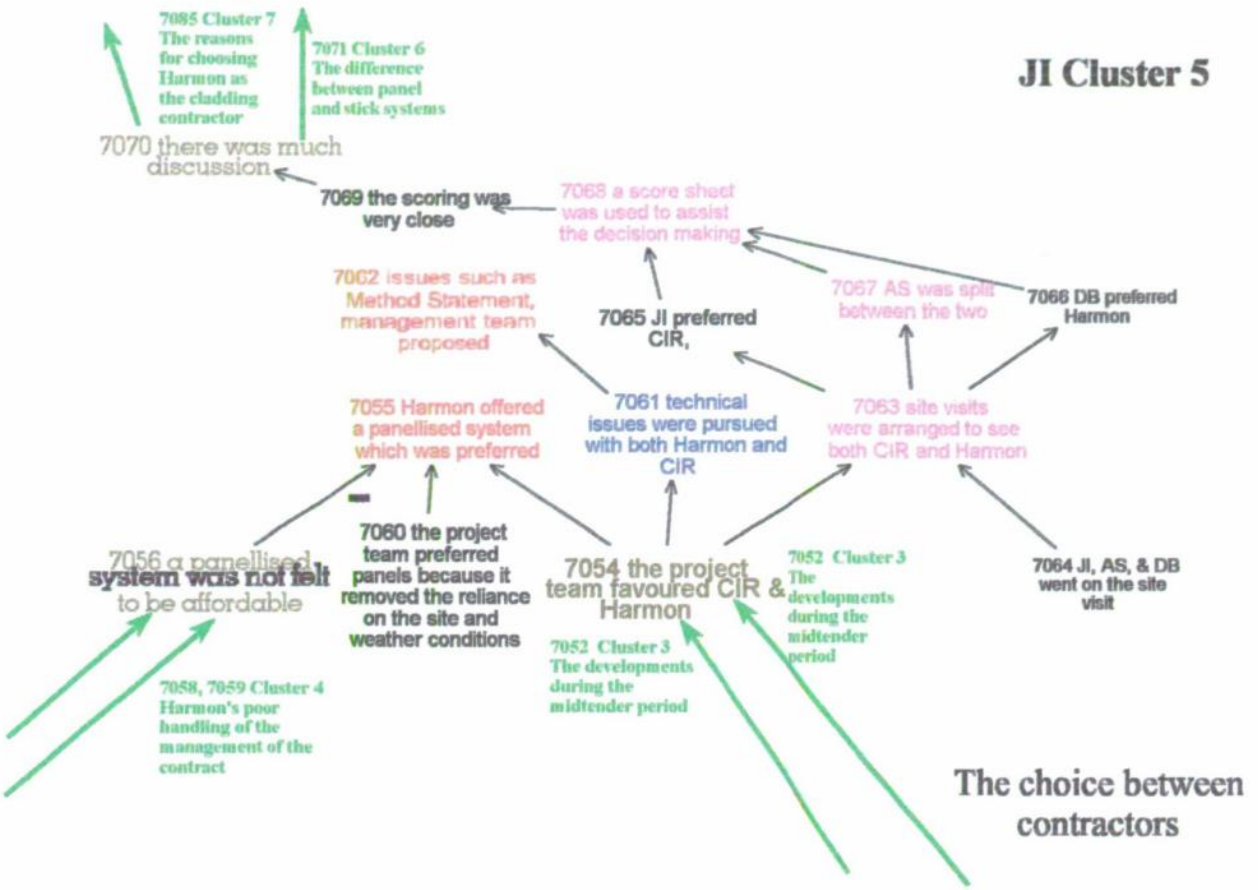


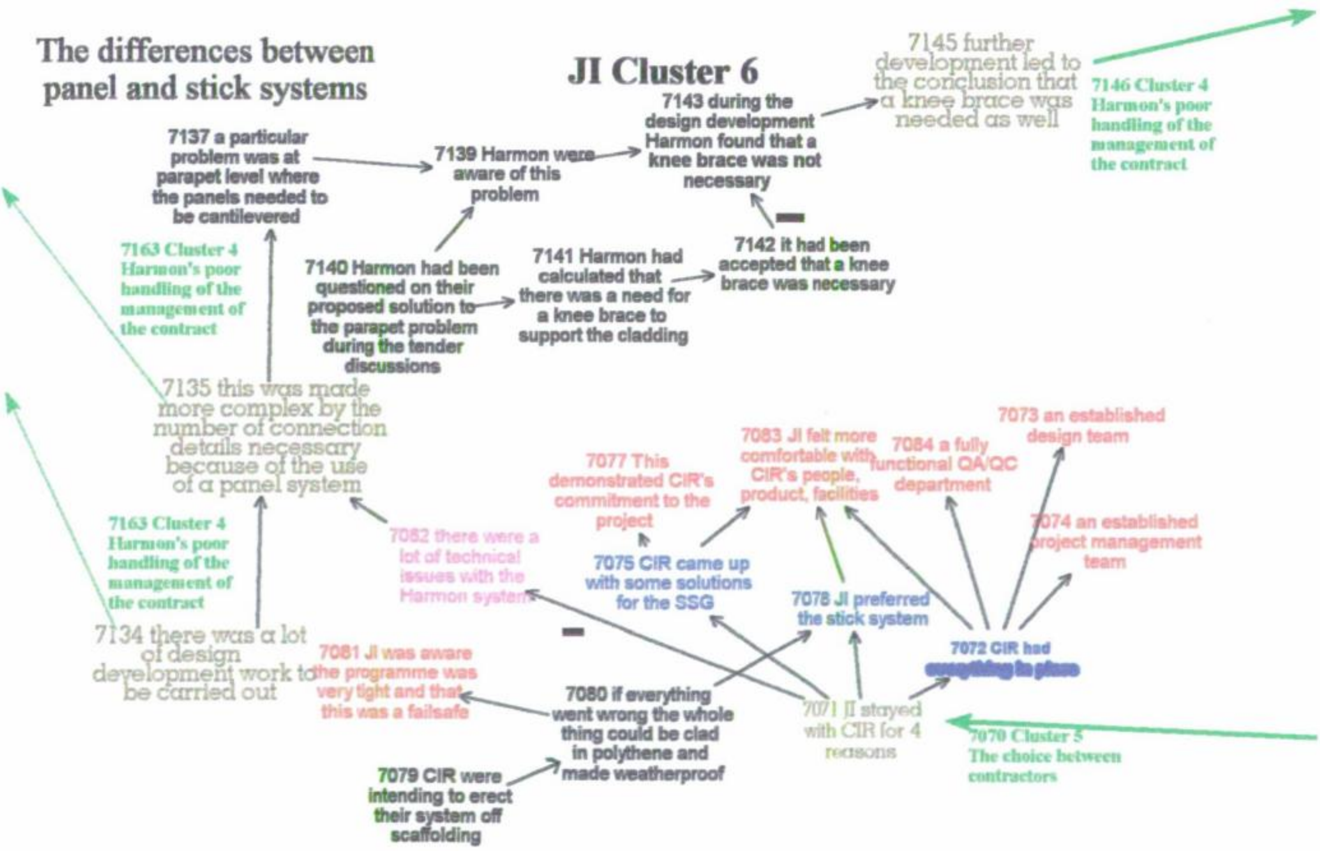
The developments during the midtender period

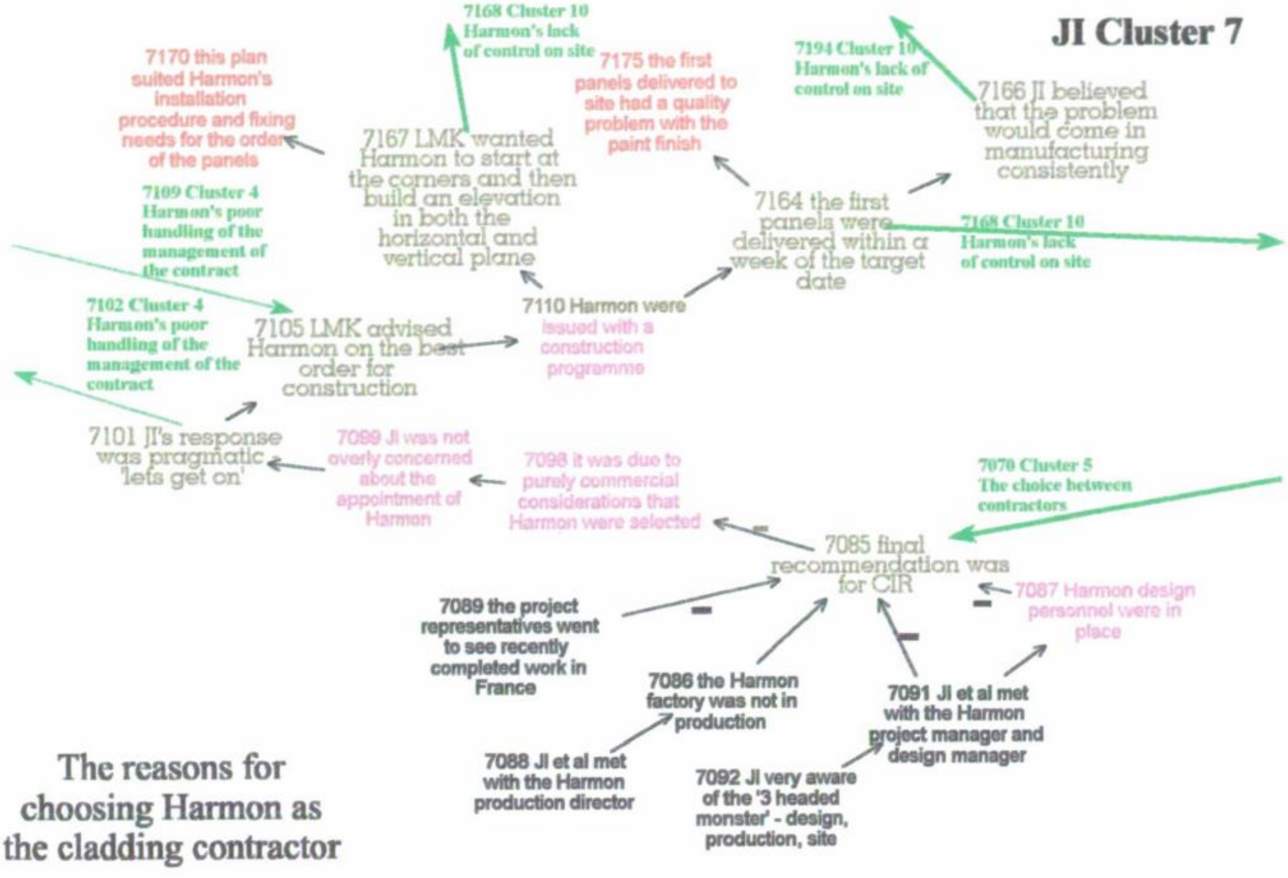
JI Cluster 4



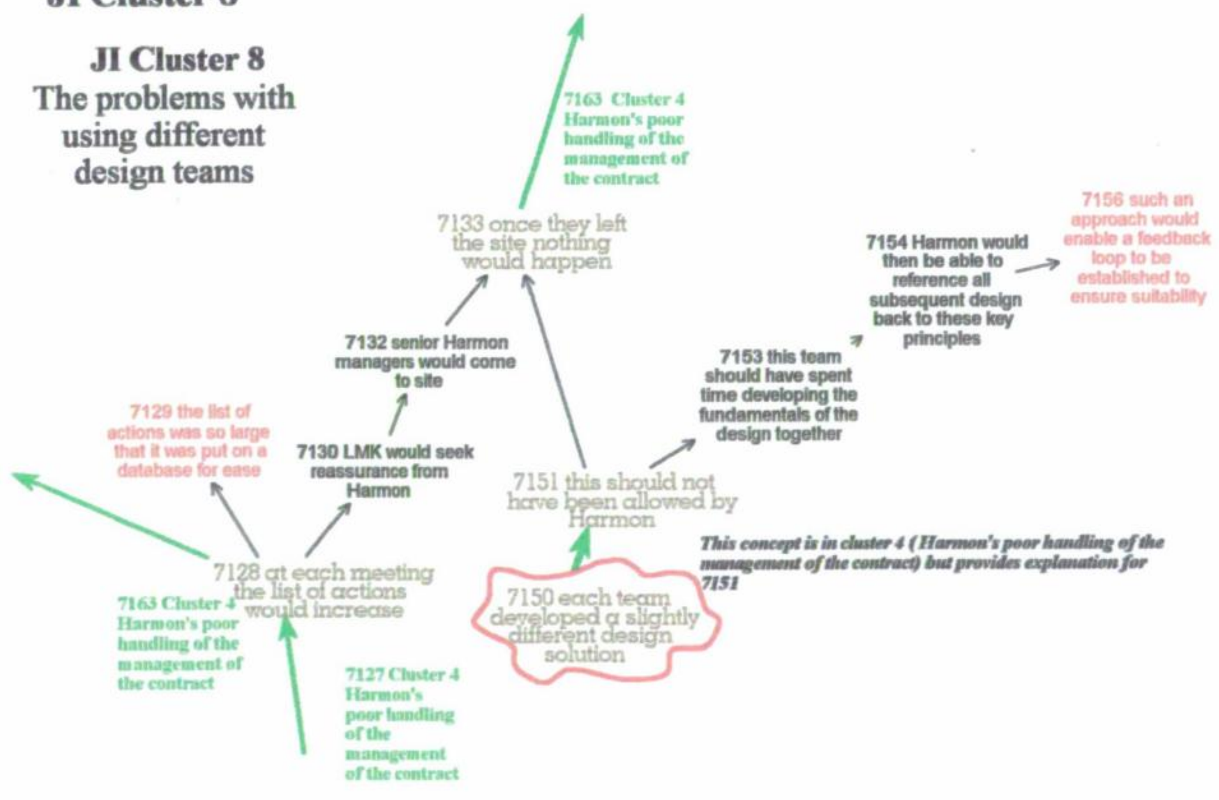
Harmon's poor handling of the management of the contract


JI Cluster 5
The choice between contractors
7085 Cluster 7 The reasons for choosing Harmon as the cladding contractor
7071 Cluster 6 The difference between panel and stick systems
7070 there was much discussion
7069 the scoring was very close
7068 a score sheet was used to assist the decision making
7062 issues such as Method Statement, management team proposed
7065 JI preferred CIR,
7067 AS was split between the two
7066 DB preferred Harmon
7055 Harmon offered a panellised system which was preferred
7061 technical issues were pursued with both Harmon and CIR
7063 site visits were arranged to see both CIR and Harmon
7056 a panellised system was not felt to be affordable
7060 the project team preferred panels because it removed the reliance on the site and weather conditions
7054 the project team favoured CIR & Harmon
7052 Cluster 3 The developments during the midtender period
7064 JI, AS, & DB went on the site visit
7052 Cluster 3 The developments during the midtender period
7058, 7059 Cluster 4 Harmon's poor handling of the management of the contract

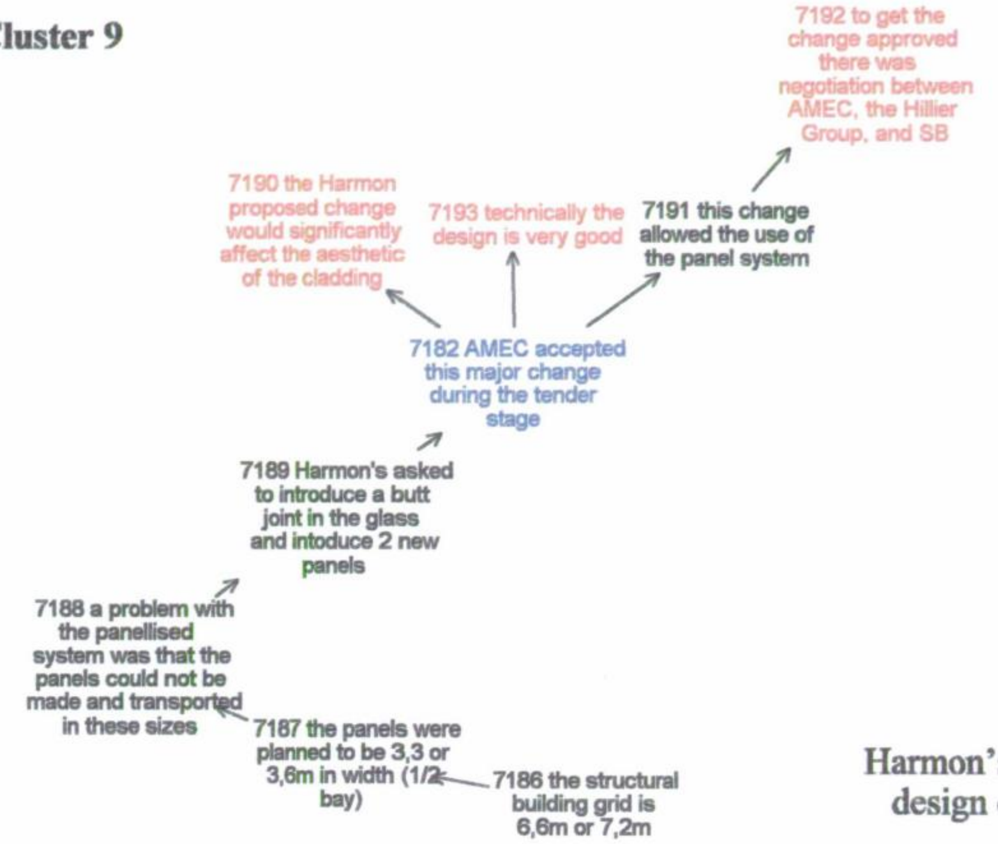

The differences between panel and stick systems
JI Cluster 6
7145 further development led to the conclusion that a knee brace was needed as well
7146 Cluster 4 Harmon's poor handling of the management of the contract
7143 during the design development Harmon found that a knee brace was not necessary
7137 a particular problem was at parapet level where the panels needed to be cantilevered
7139 Harmon were aware of this problem
7142 it had been accepted that a knee brace was necessary
7163 Cluster 4 Harmon's poor handling of the management of the contract
7140 Harmon had been questioned on their proposed solution to the parapet problem during the tender discussions
7141 Harmon had calculated that there was a need for a knee brace to support the cladding
7135 this was made more complex by the number of connection details necessary because of the use of a panel system
7073 an established design team
7083 JI felt more comfortable with CIR's people, product, facilities
7084 a fully functional QA/QC department
7077 This demonstrated CIR's commitment to the project
7074 an established project management team
7163 Cluster 4 Harmon's poor handling of the management of the contract
7082 there were a lot of technical issues with the Harmon system
7075 CIR came up with some solutions for the SSG
7078 JI preferred the stick system
7072 CIR had everything in place
7134 there was a lot of design development work to be carried out
7081 JI was aware the programme was very tight and that this was a failsafe
7080 if everything went wrong the whole thing could be clad in polythene and made weatherproof
7071 JI stayed with CIR for 4 reasons
7070 Cluster 5 The choice between contractors
7079 CIR were intending to erect their system off scaffolding


JI Cluster 7
7168 Cluster 10 Harmon's lack of control on site
7170 this plan suited Harmon's installation procedure and fixing needs for the order of the panels
7175 the first panels delivered to site had a quality problem with the paint finish
7194 Cluster 10 Harmon's lack of control on site
7166 JI believed that the problem would come in manufacturing consistently
7167 LMK wanted Harmon to start at the corners and then build an elevation in both the horizontal and vertical plane
7109 Cluster 4 Harmon's poor handling of the management of the contract
7164 the first panels were delivered within a week of the target date
7168 Cluster 10 Harmon's lack of control on site
7102 Cluster 4 Harmon's poor handling of the management of the contract
7105 LMK advised Harmon on the best order for construction
7110 Harmon were issued with a construction programme
7101 JI's response was pragmatic 'lets get on'
7099 JI was not overly concerned about the appointment of Harmon
7098 it was due to purely commercial considerations that Harmon were selected
7070 Cluster 5 The choice between contractors
7085 final recommendation was for CIR
7089 the project representatives went to see recently completed work in France
7087 Harmon design personnel were in place
7086 the Harmon factory was not in production
7091 JI et al met with the Harmon project manager and design manager
7088 JI et al met with the Harmon production director
7092 JI very aware of the '3 headed monster' - design, production, site
The reasons for choosing Harmon as the cladding contractor

JI Cluster 8


JI Cluster 8
The problems with using different design teams
7163 Cluster 4 Harmon's poor handling of the management of the contract
7133 once they left the site nothing would happen
7156 such an approach would enable a feedback loop to be established to ensure suitability
7154 Harmon would then be able to reference all subsequent design back to these key principles
7132 senior Harmon managers would come to site
7153 this team should have spent time developing the fundamentals of the design together
7129 the list of actions was so large that it was put on a database for ease
7130 LMK would seek reassurance from Harmon
7151 this should not have been allowed by Harmon
This concept is in cluster 4 (Harmon's poor handling of the management of the contract) but provides explanation for 7151
7128 at each meeting the list of actions would increase
7163 Cluster 4 Harmon's poor handling of the management of the contract
7150 each team developed a slightly different design solution
7127 Cluster 4 Harmon's poor handling of the management of the contract

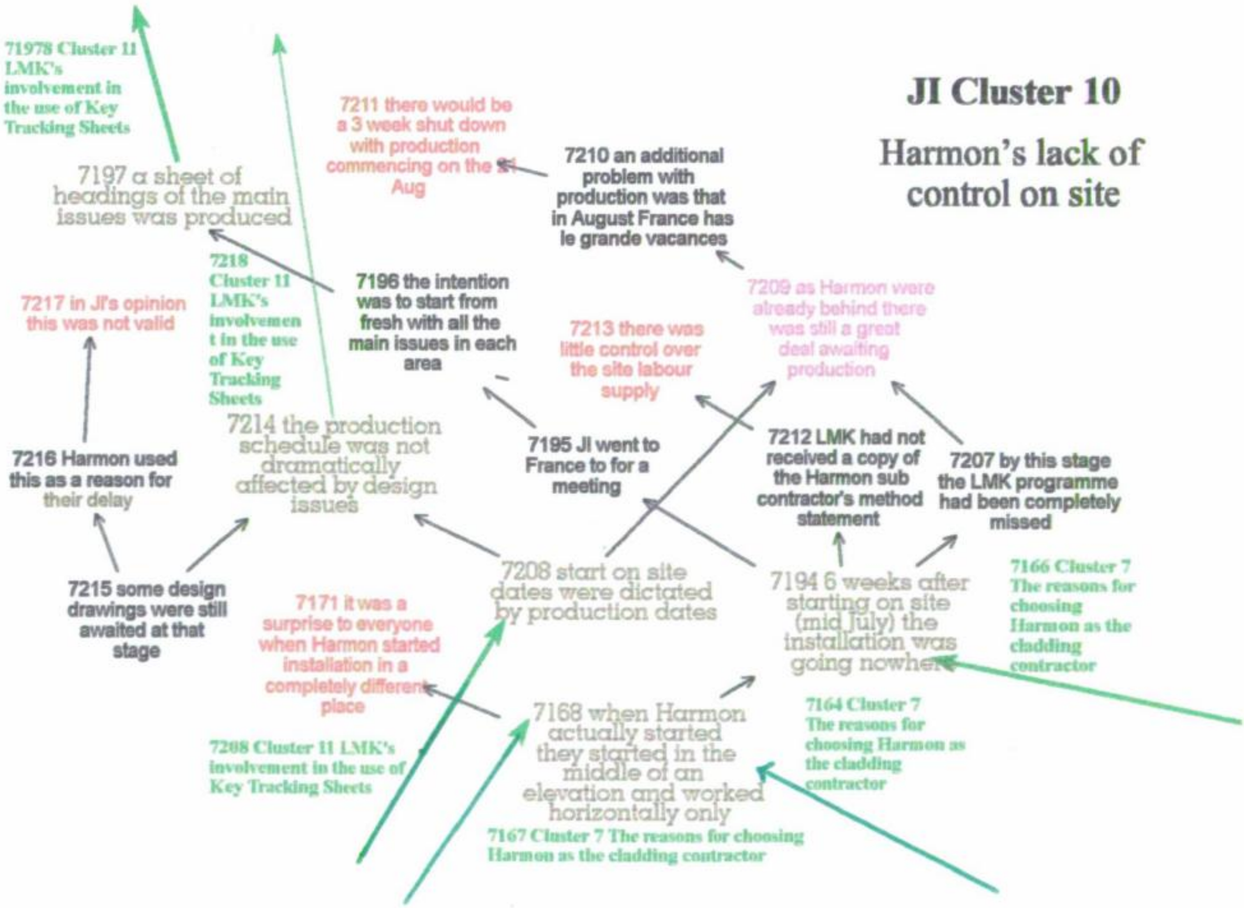
JI Cluster 9



Harmon's required design changes

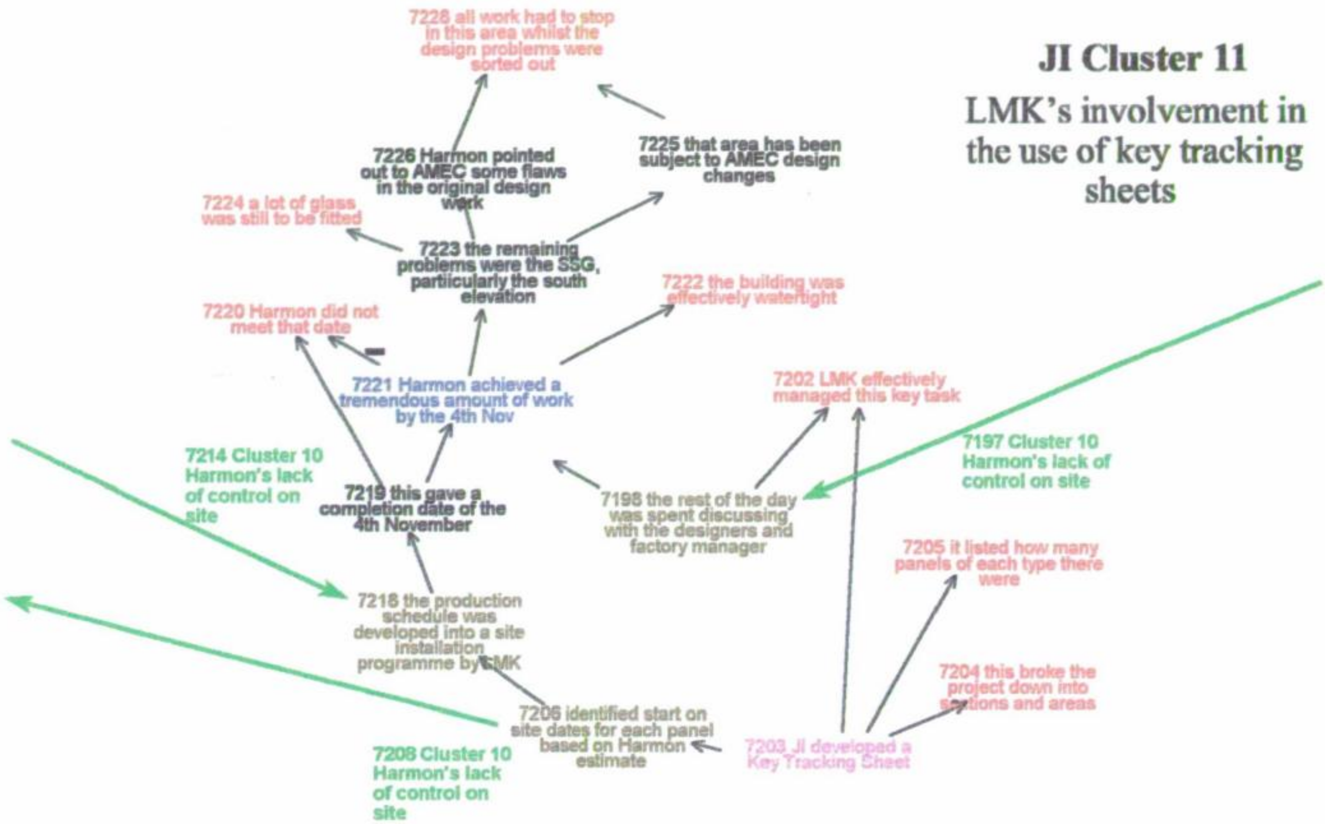
JI Cluster 10

Harmon's lack of control on site



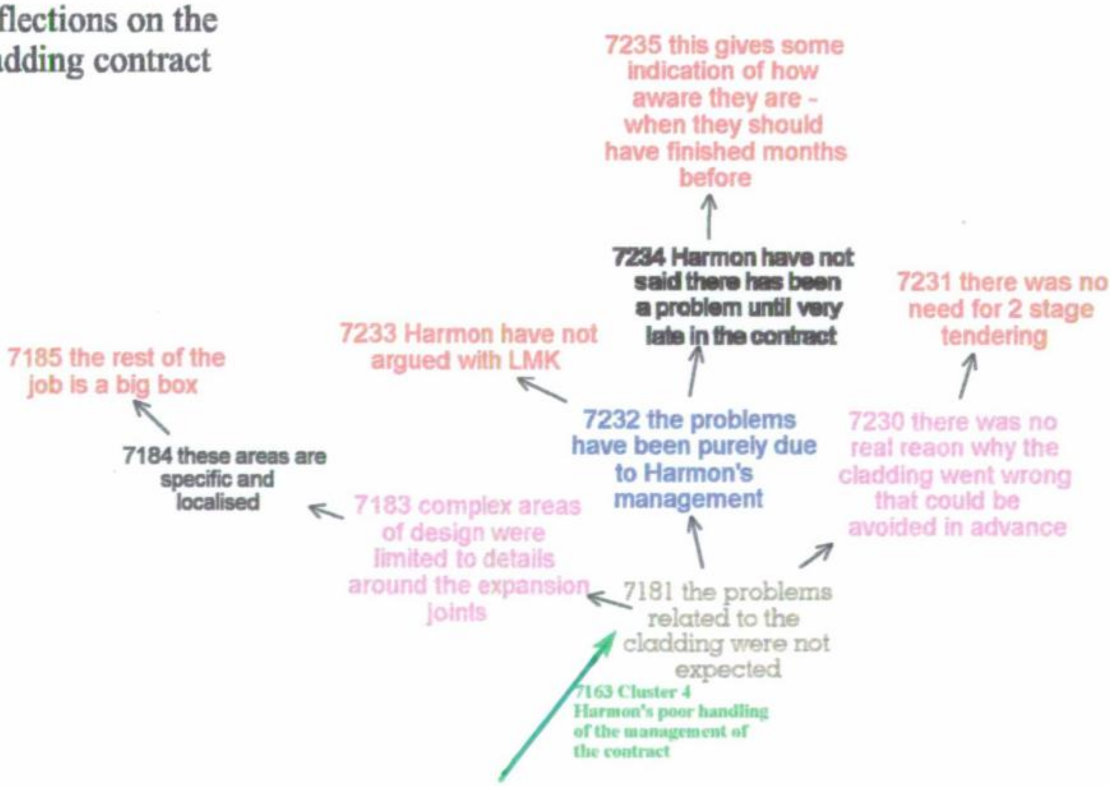
JI Cluster 11

LMK's involvement in the use of key tracking sheets



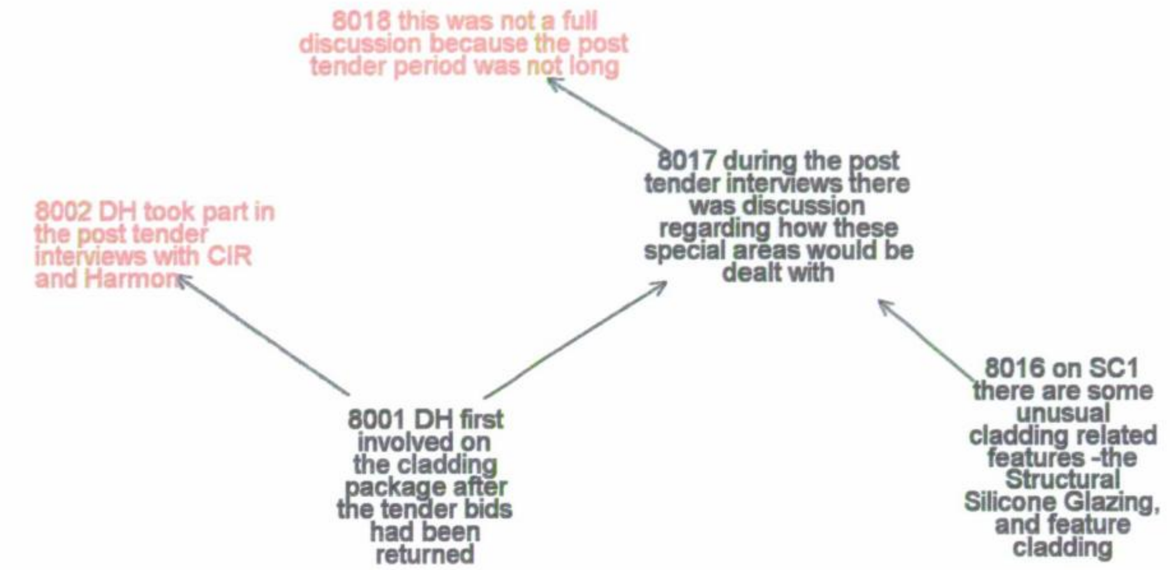
JI Cluster 12

Reflections on the cladding contract



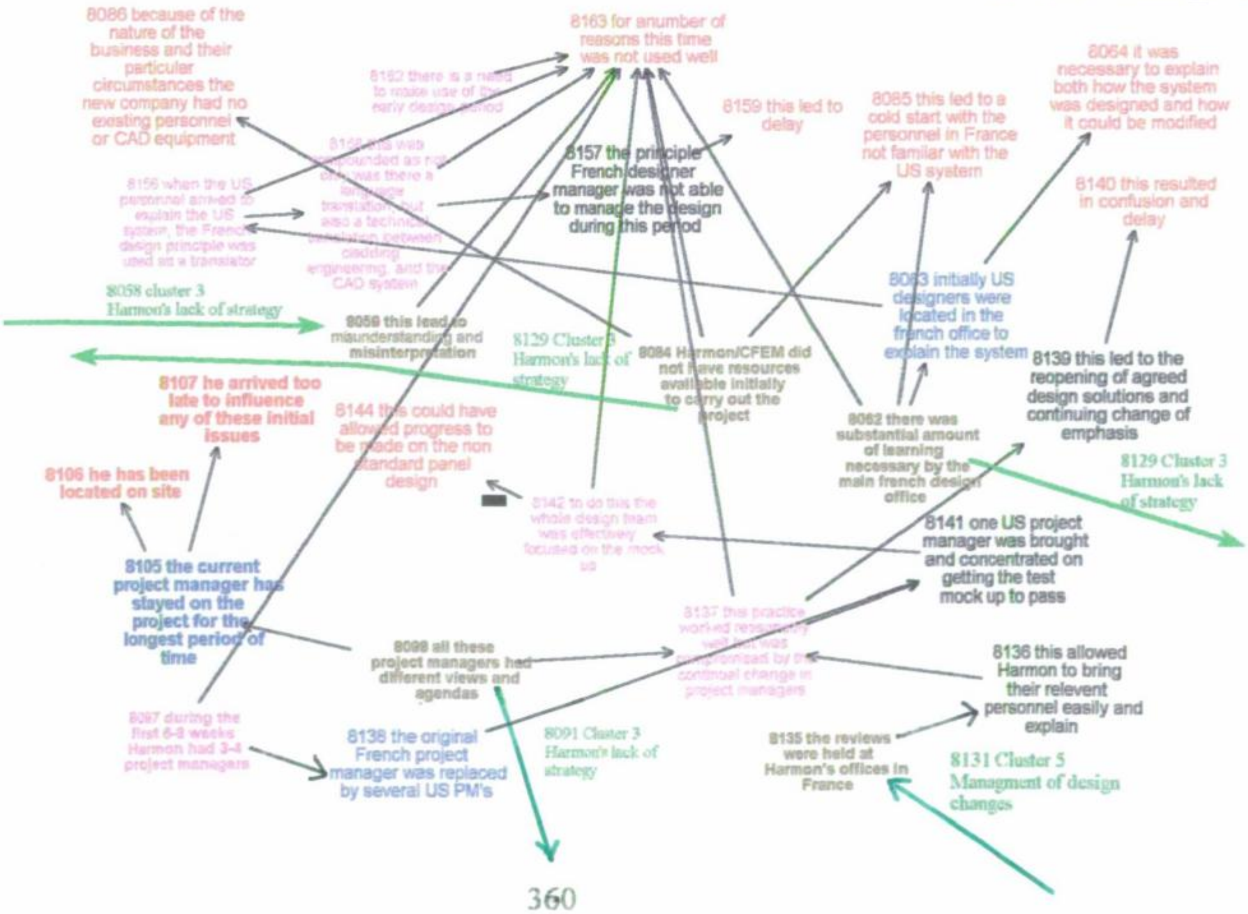
DH Cluster 1

Post tender period issues

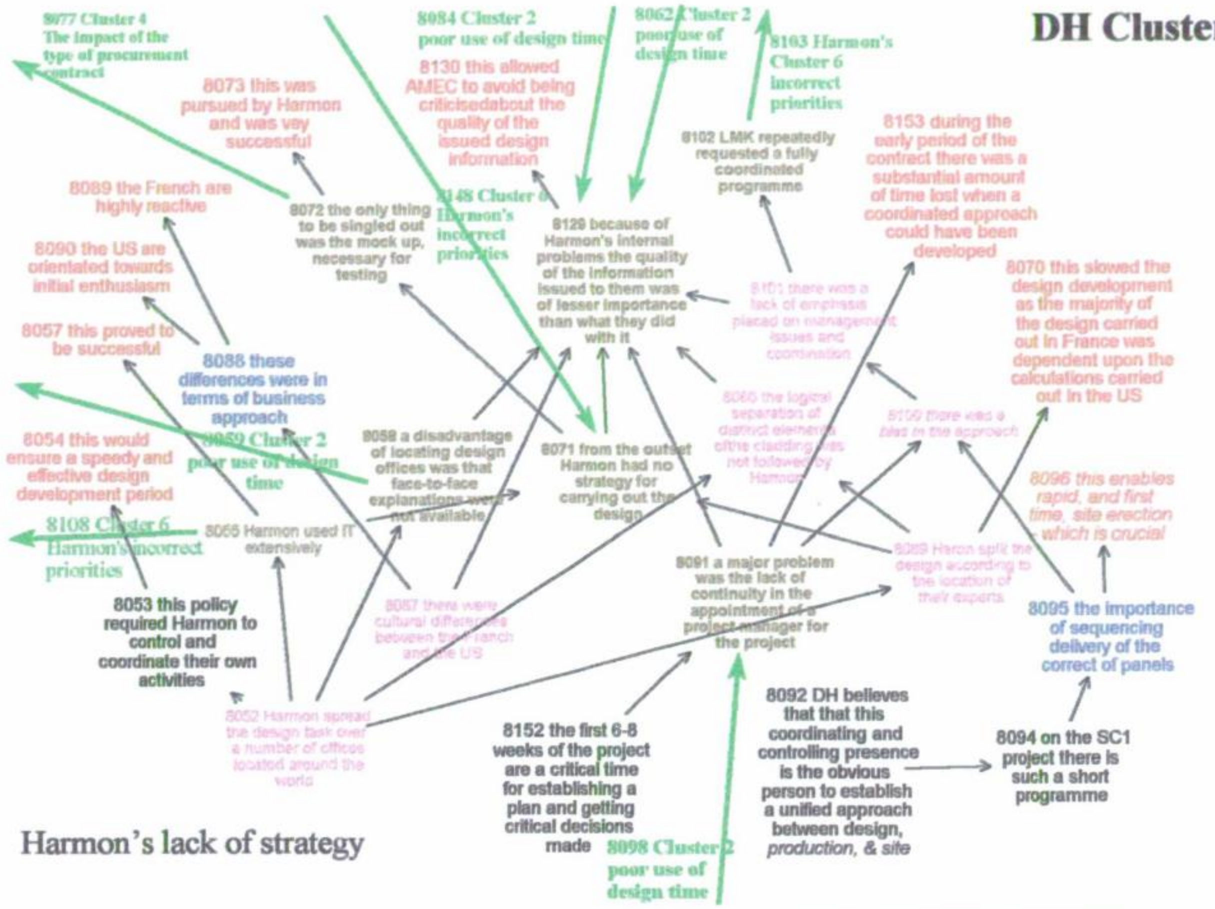


DH Cluster 2

Poor use of design time



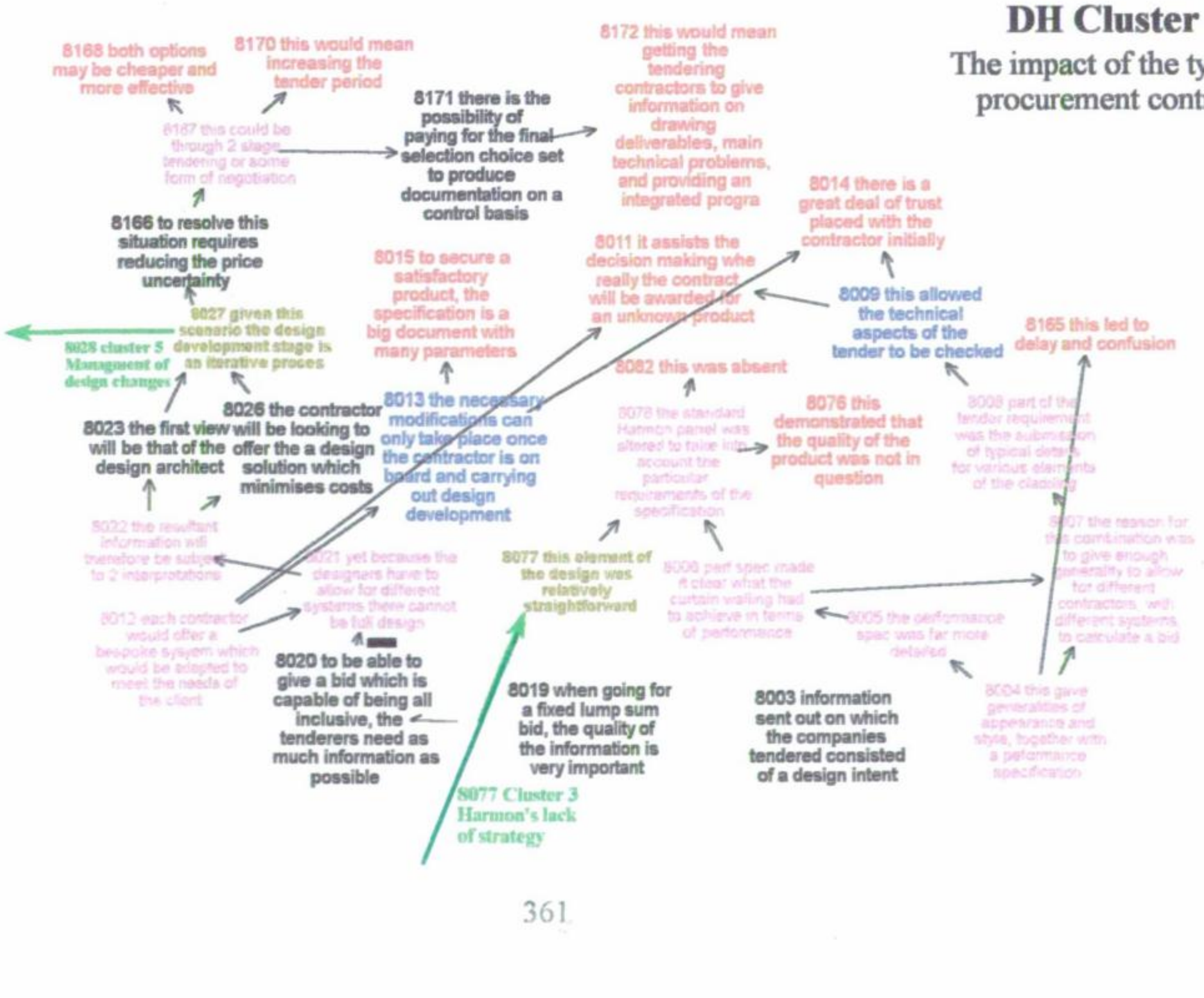
DH Cluster 3



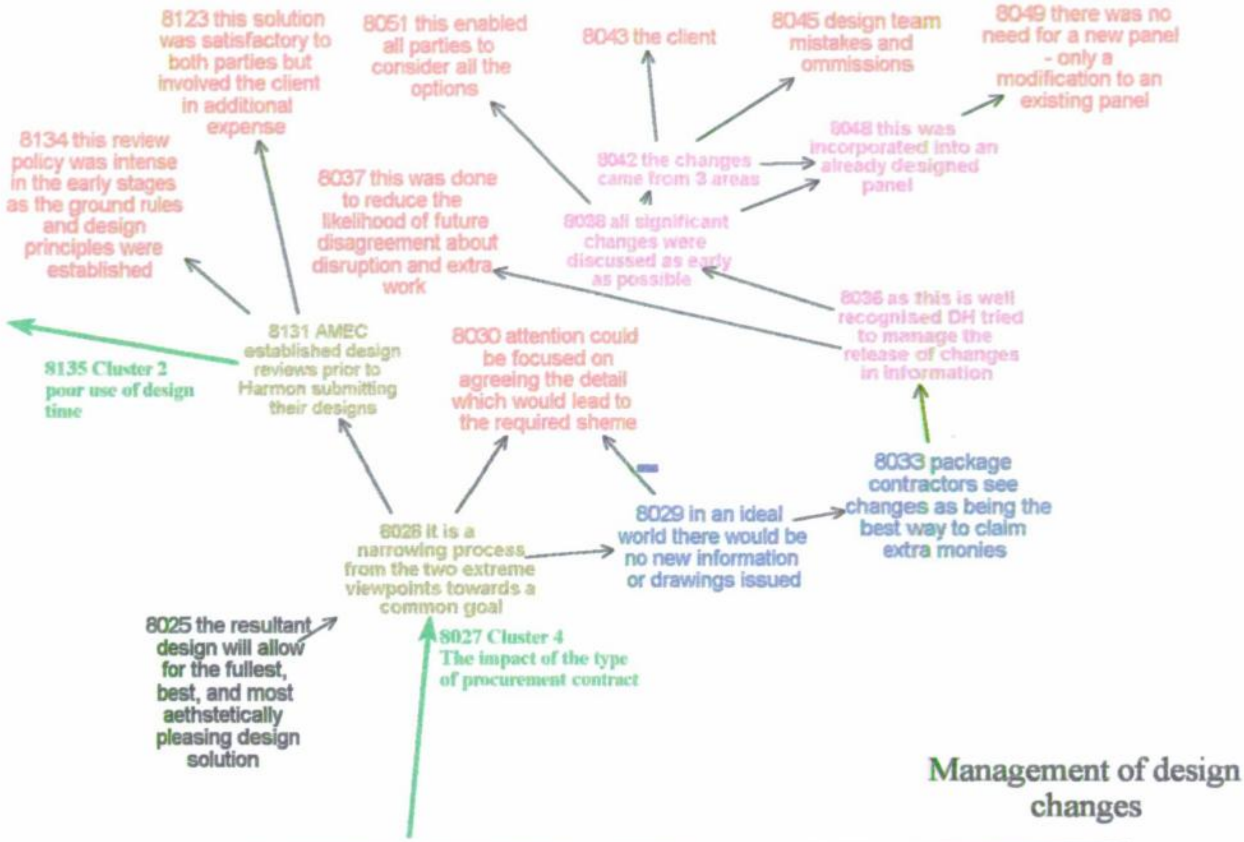
Harmon's lack of strategy

DH Cluster 4

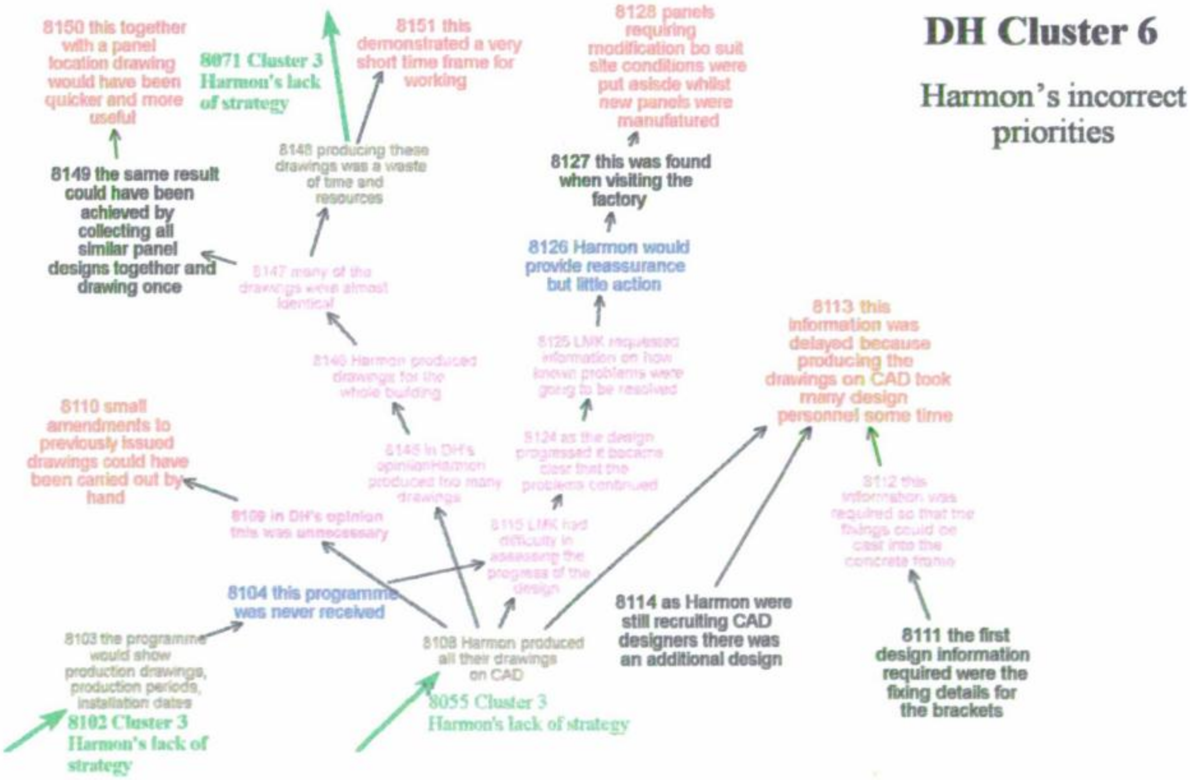
The impact of the type of procurement contract

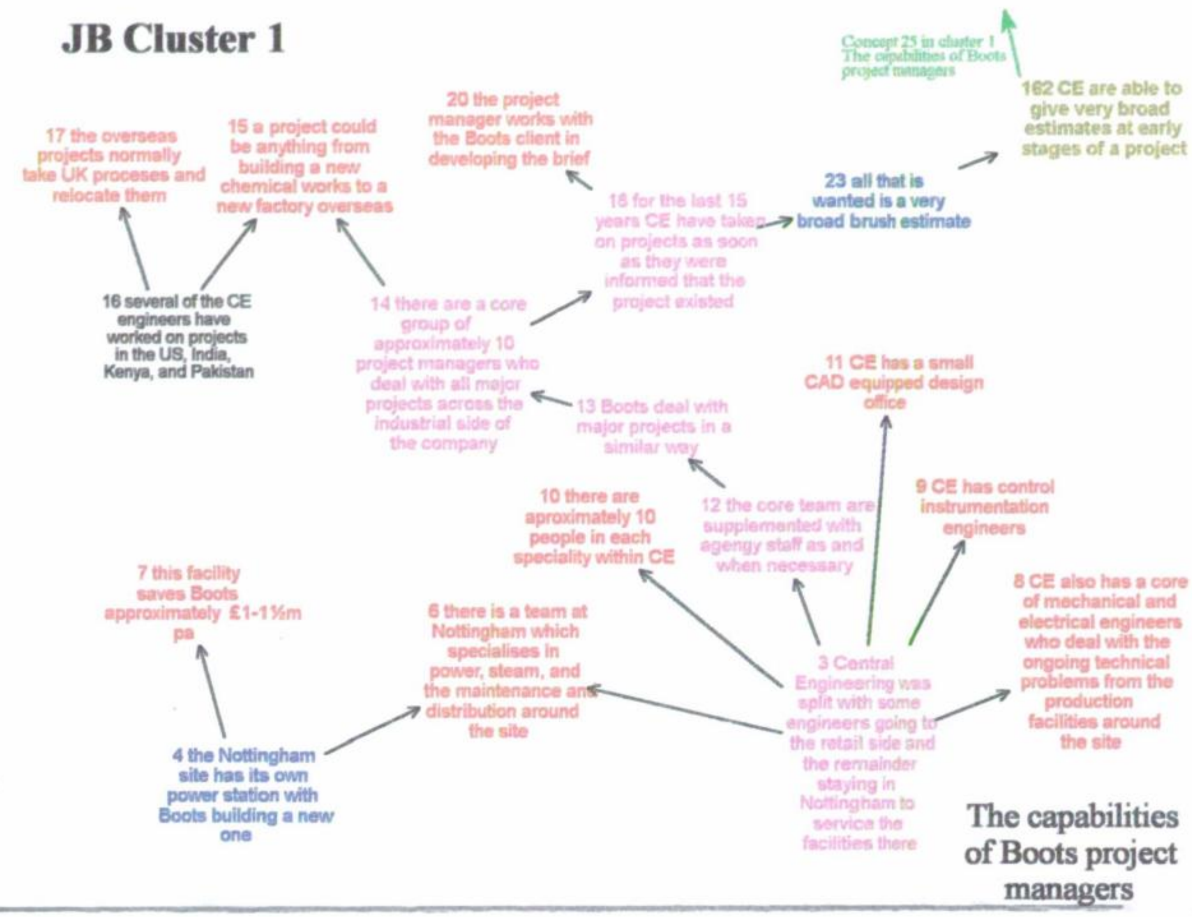


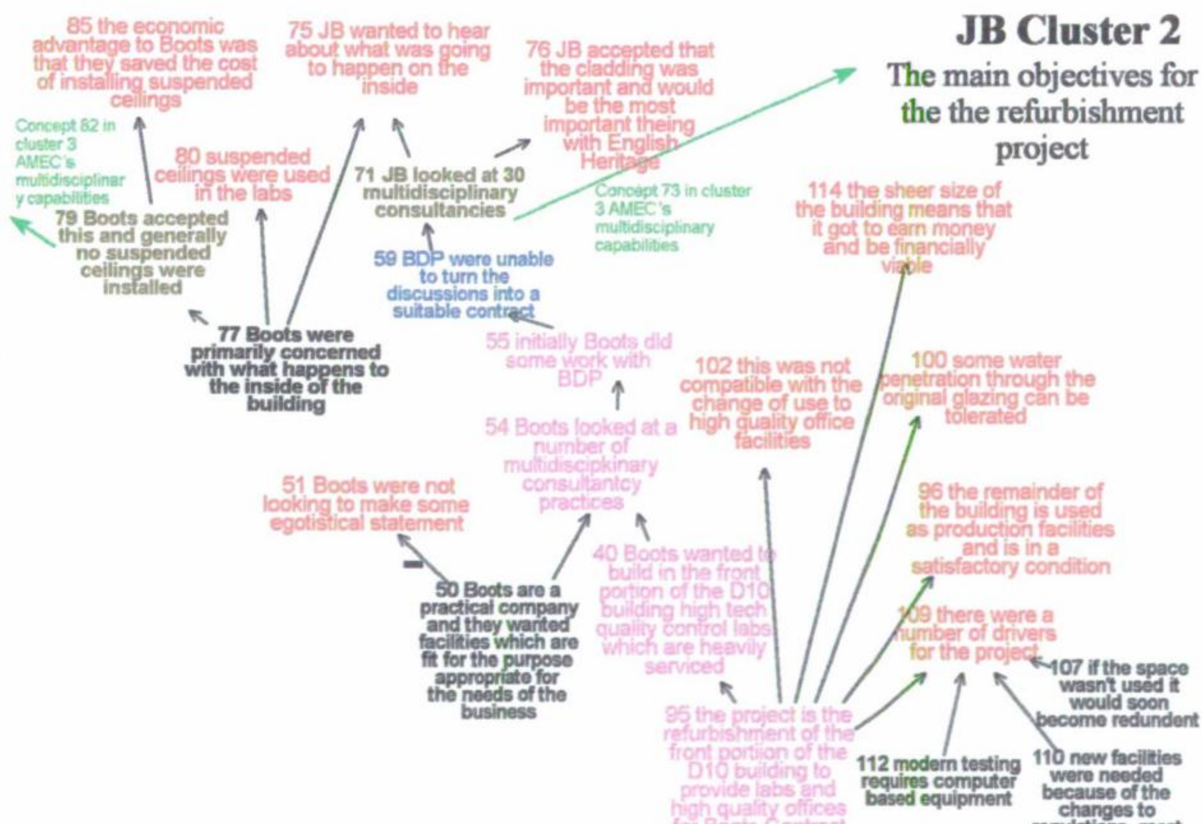
DH Cluster 5

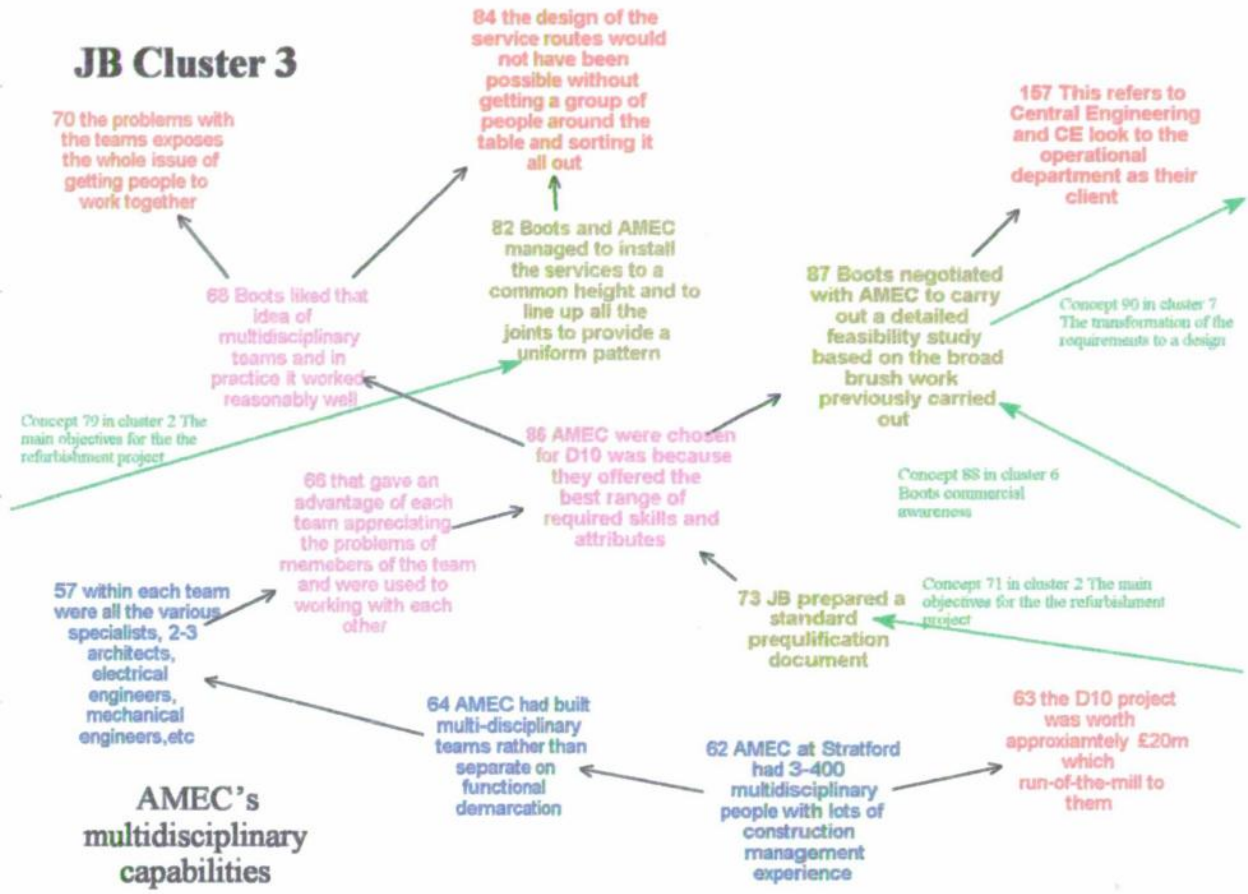


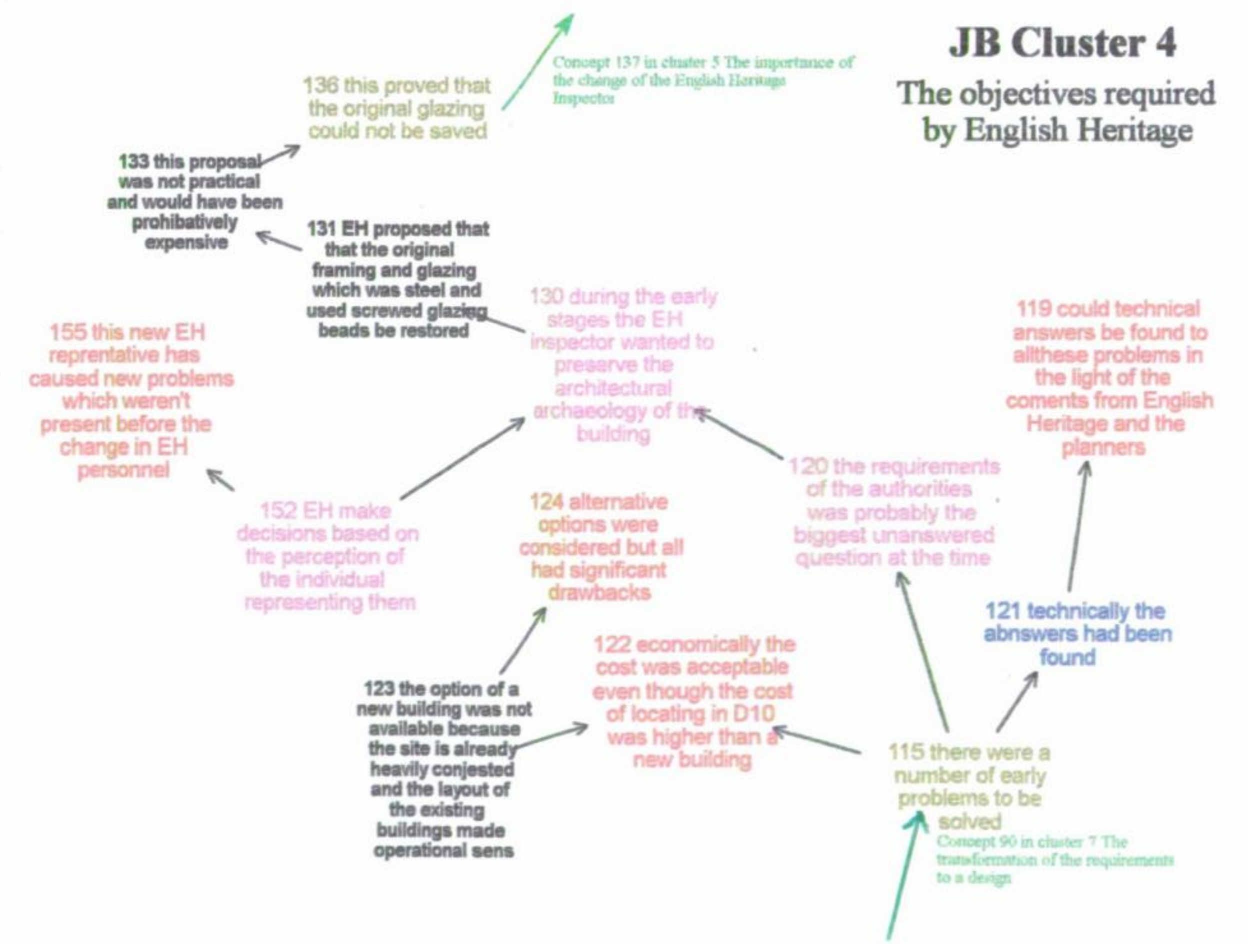
DH Cluster 6



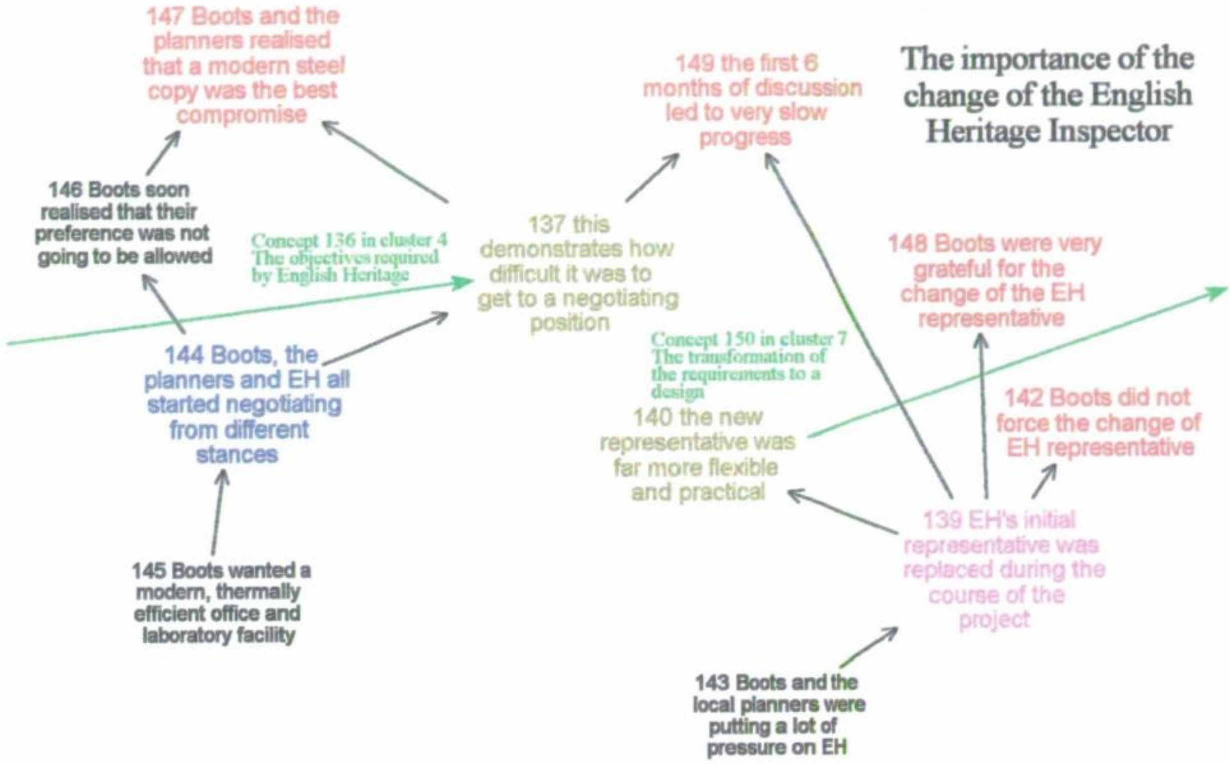

JB Cluster 1
Concept 25 in cluster 1 The capabilities of Boots project managers
162 CE are able to give very broad estimates at early stages of a project
23 all that is wanted is a very broad brush estimate
20 the project manager works with the Boots client in developing the brief
17 the overseas projects normally take UK proceses and relocate them
15 a project could be anything from building a new chemical works to a new factory overseas
16 for the last 15 years CE have taken on projects as soon as they were informed that the project existed
16 several of the CE engineers have worked on projects in the US, India, Kenya, and Pakistan
14 there are a core group of approximately 10 project managers who deal with all major projects across the industrial side of the company
13 Boots deal with major projects in a similar way
11 CE has a small CAD equipped design office
10 there are aproximately 10 people in each speciality within CE
12 the core team are supplemented with agengy staff as and when necessary
9 CE has control instrumentation engineers
7 this facility saves Boots approximately £1-1½m pa
6 there is a team at Nottingham which specialises in power, steam, and the maintenance and distribution around the site
8 CE also has a core of mechanical and electrical engineers who deal with the ongoing technical problems from the production facilities around the site
3 Central Engineering was split with some engineers going to the retail side and the remainder staying in Nottingham to service the facilities there
4 the Nottingham site has its own power station with Boots building a new one
The capabilities of Boots project managers


JB Cluster 2
The main objectives for the the refurbishment project
85 the economic advantage to Boots was that they saved the cost of installing suspended ceilings
75 JB wanted to hear about what was going to happen on the inside
76 JB accepted that the cladding was important and would be the most important theing with English Heritage
Concept 82 in cluster 3 AMEC's multidisciplinary capabilities
80 suspended ceilings were used in the labs
71 JB looked at 30 multidisciplinary consultancies
Concept 73 in cluster 3 AMEC's multidisciplinary capabilities
114 the sheer size of the building means that it got to earn money and be financially viable
79 Boots accepted this and generally no suspended ceilings were installed
59 BDP were unable to turn the discussions into a suitable contract
77 Boots were primarily concerned with what happens to the inside of the building
55 initially Boots did some work with BDP
102 this was not compatible with the change of use to high quality office facilities
100 some water penetration through the original glazing can be tolerated
54 Boots looked at a number of multidiscipkinary consultantcy practices
51 Boots were not looking to make some egotistical statement
96 the remainder of the building is used as production facilities and is in a satisfactory condition
40 Boots wanted to build in the front portion of the D10 building high tech quality control labs which are heavily serviced
50 Boots are a practical company and they wanted facilities which are fit for the purpose appropriate for the needs of the business
109 there were a number of drivers for the project
107 if the space wasn't used it would soon become redundent
95 the project is the refurbishment of the front portion of the D10 building to provide labs and high quality offices for Boots Contract Manufacturing
112 modern testing requires computer based equipment
110 new facilities were needed because of the changes to regulations, most notably COSH

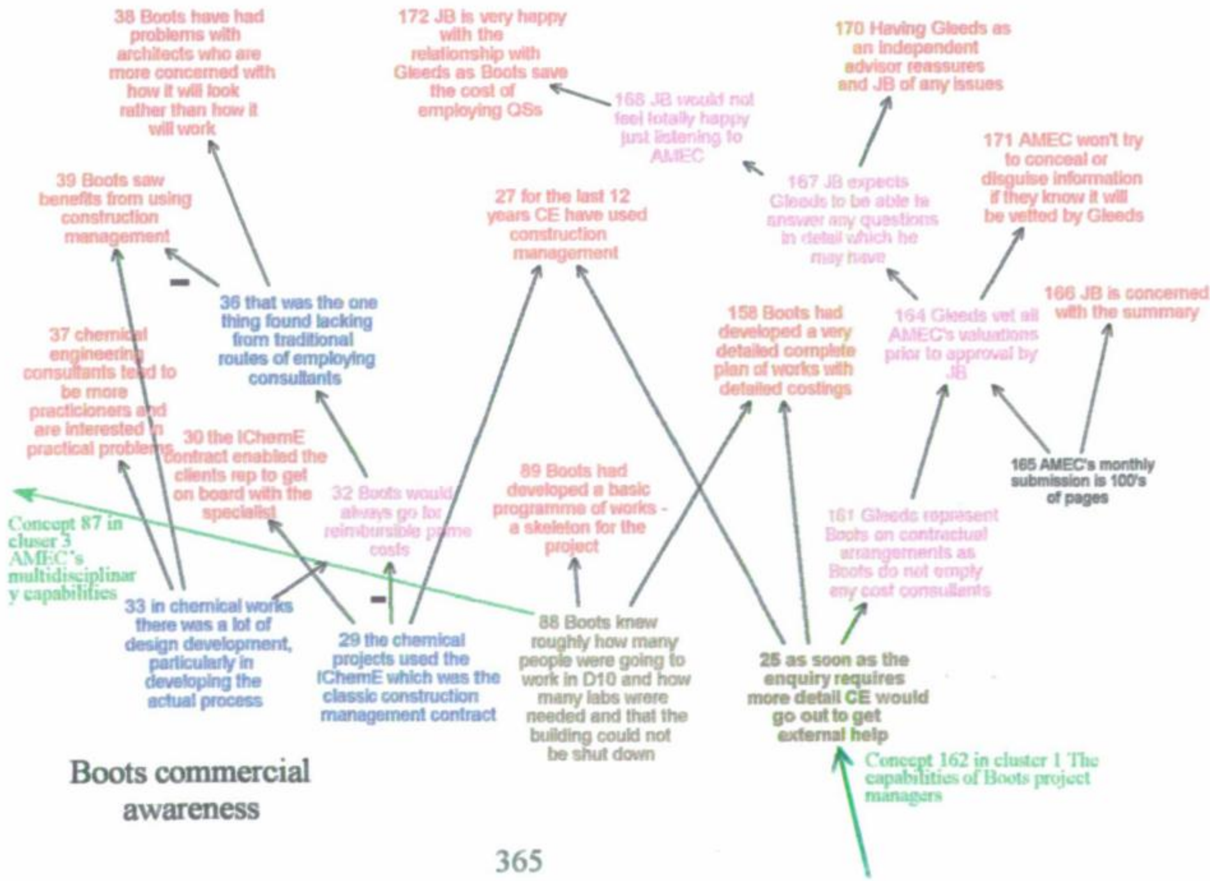

JB Cluster 3
70 the problems with the teams exposes the whole issue of getting people to work together
84 the design of the service routes would not have been possible without getting a group of people around the table and sorting it all out
157 This refers to Central Engineering and CE look to the operational department as their client
82 Boots and AMEC managed to install the services to a common height and to line up all the joints to provide a uniform pattern
68 Boots liked that idea of multidisciplinary teams and in practice it worked reasonably well
87 Boots negotiated with AMEC to carry out a detailed feasibility study based on the broad brush work previously carried out
Concept 90 in cluster 7 The transformation of the requirements to a design
Concept 79 in cluster 2 The main objectives for the the refurbishment project
86 AMEC were chosen for D10 was because they offered the best range of required skills and attributes
Concept 88 in cluster 6 Boots commercial awareness
66 that gave an advantage of each team appreciating the problems of memebers of the team and were used to working with each other
57 within each team were all the various specialists, 2-3 architects, electrical engineers, mechanical engineers,etc
73 JB prepared a standard prequlification document
Concept 71 in cluster 2 The main objectives for the the refurbishment project
64 AMEC had built multi-disciplinary teams rather than separate on functional demarcation
62 AMEC at Stratford had 3-400 multidisciplinary people with lots of construction management experience
63 the D10 project was worth approxiamtely £20m which run-of-the-mill to them
AMEC's multidisciplinary capabilities


JB Cluster 4
The objectives required by English Heritage
Concept 137 in cluster 5 The importance of the change of the English Heritage Inspector
136 this proved that the original glazing could not be saved
133 this proposal was not practical and would have been prohibatively expensive
131 EH proposed that that the original framing and glazing which was steel and used screwed glazing beads be restored
130 during the early stages the EH inspector wanted to preserve the architectural archaeology of the building
155 this new EH reprentative has caused new problems which weren't present before the change in EH personnel
119 could technical answers be found to allthese problems in the light of the coments from English Heritage and the planners
152 EH make decisions based on the perception of the individual representing them
124 alternative options were considered but all had significant drawbacks
120 the requirements of the authorities was probably the biggest unanswered question at the time
121 technically the abnswers had been found
122 economically the cost was acceptable even though the cost of locating in D10 was higher than a new building
123 the option of a new building was not available because the site is already heavily conjested and the layout of the existing buildings made operational sens
115 there were a number of early problems to be solved
Concept 90 in cluster 7 The transformation of the requirements to a design

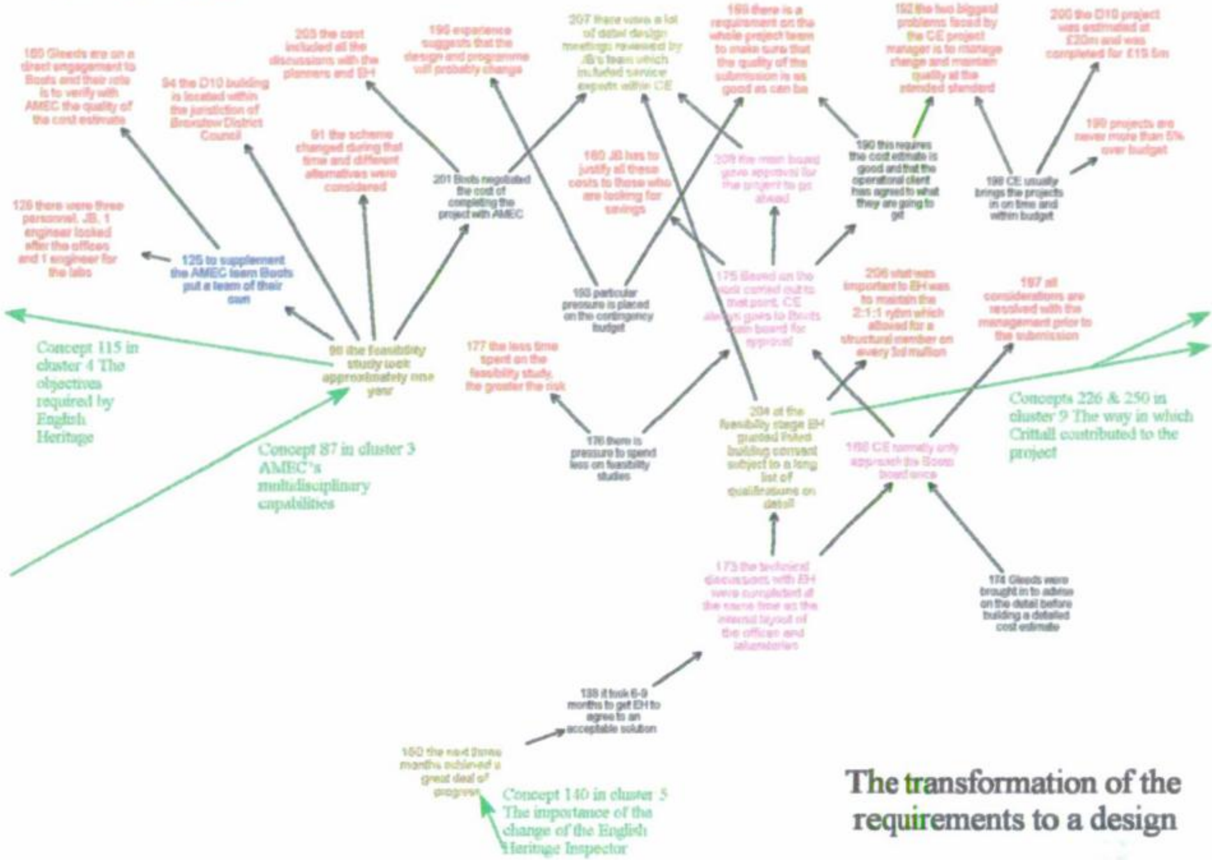
JB Cluster 5



JB Cluster 6



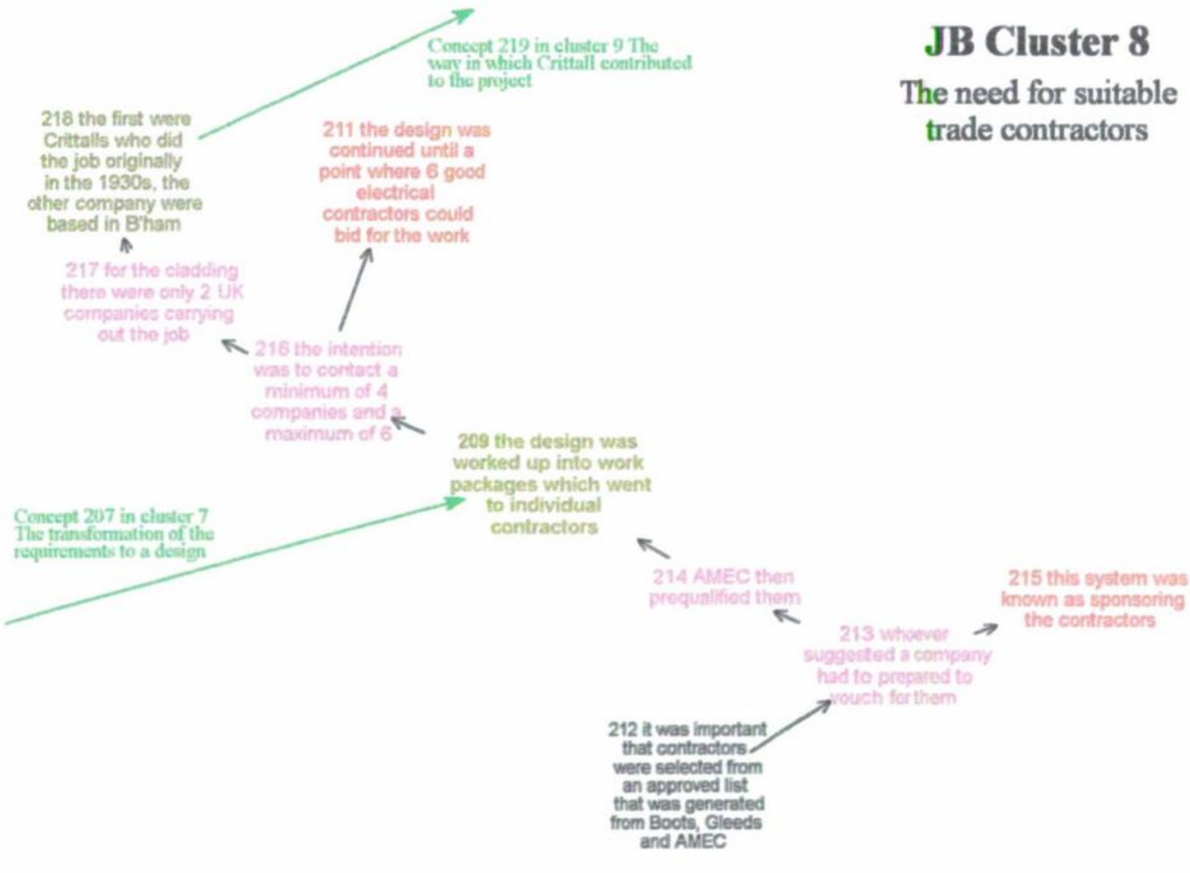
JB Cluster 7

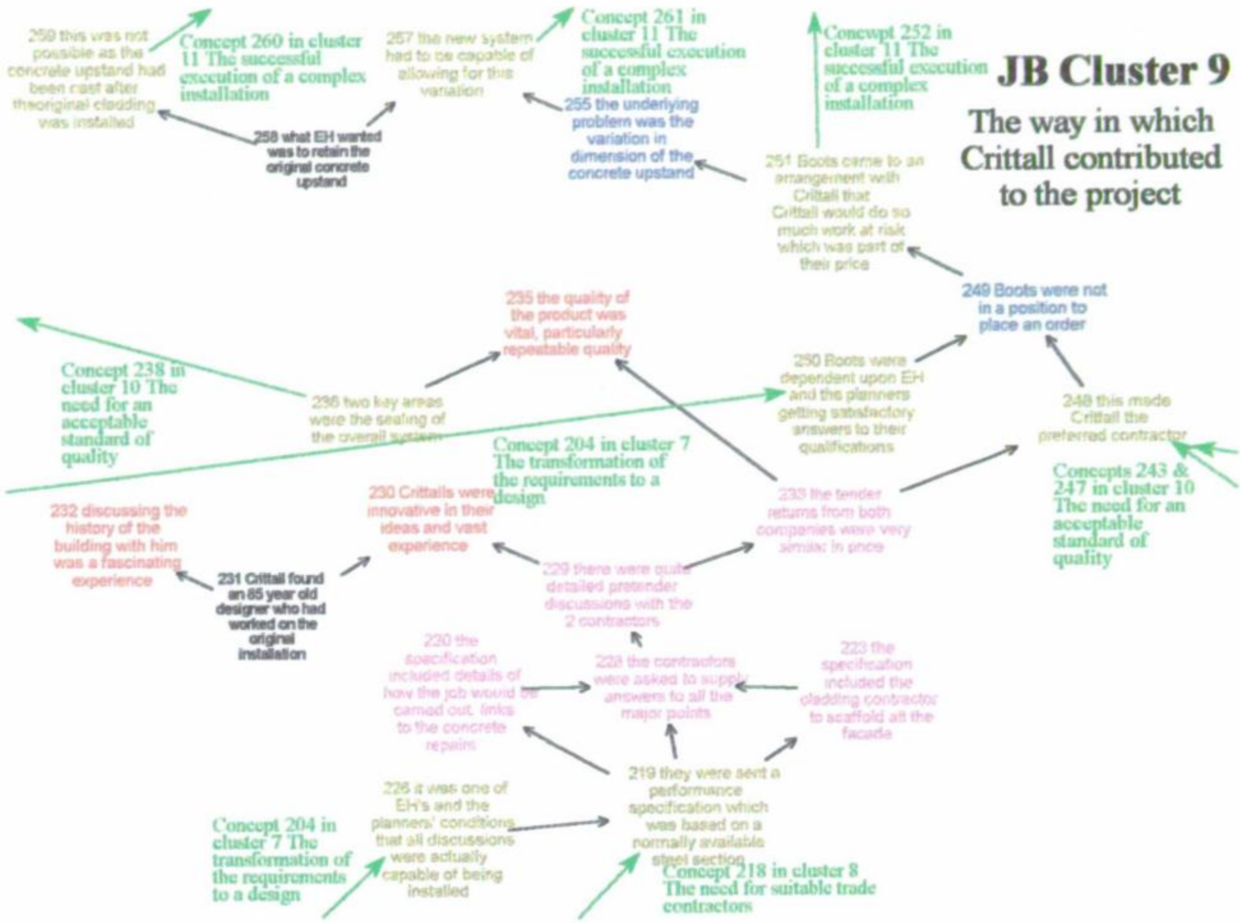


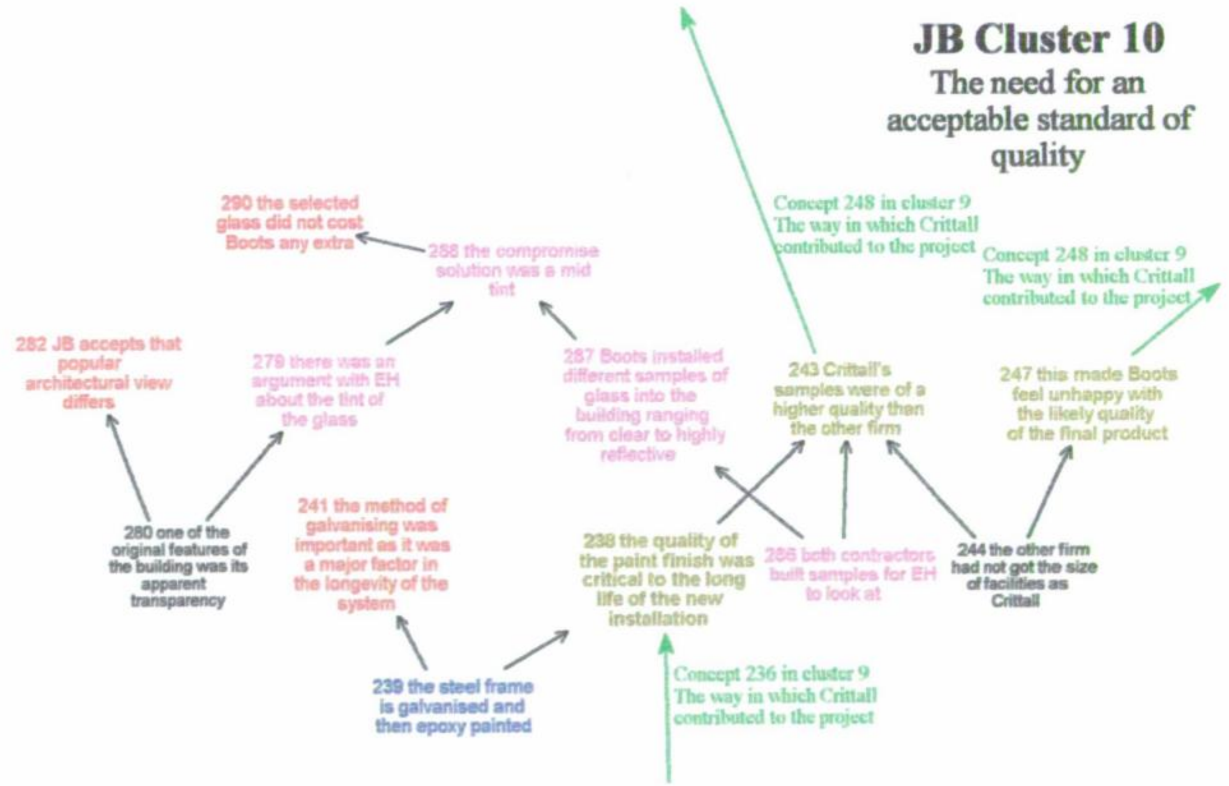
The transformation of the requirements to a design

JB Cluster 8

The need for suitable trade contractors

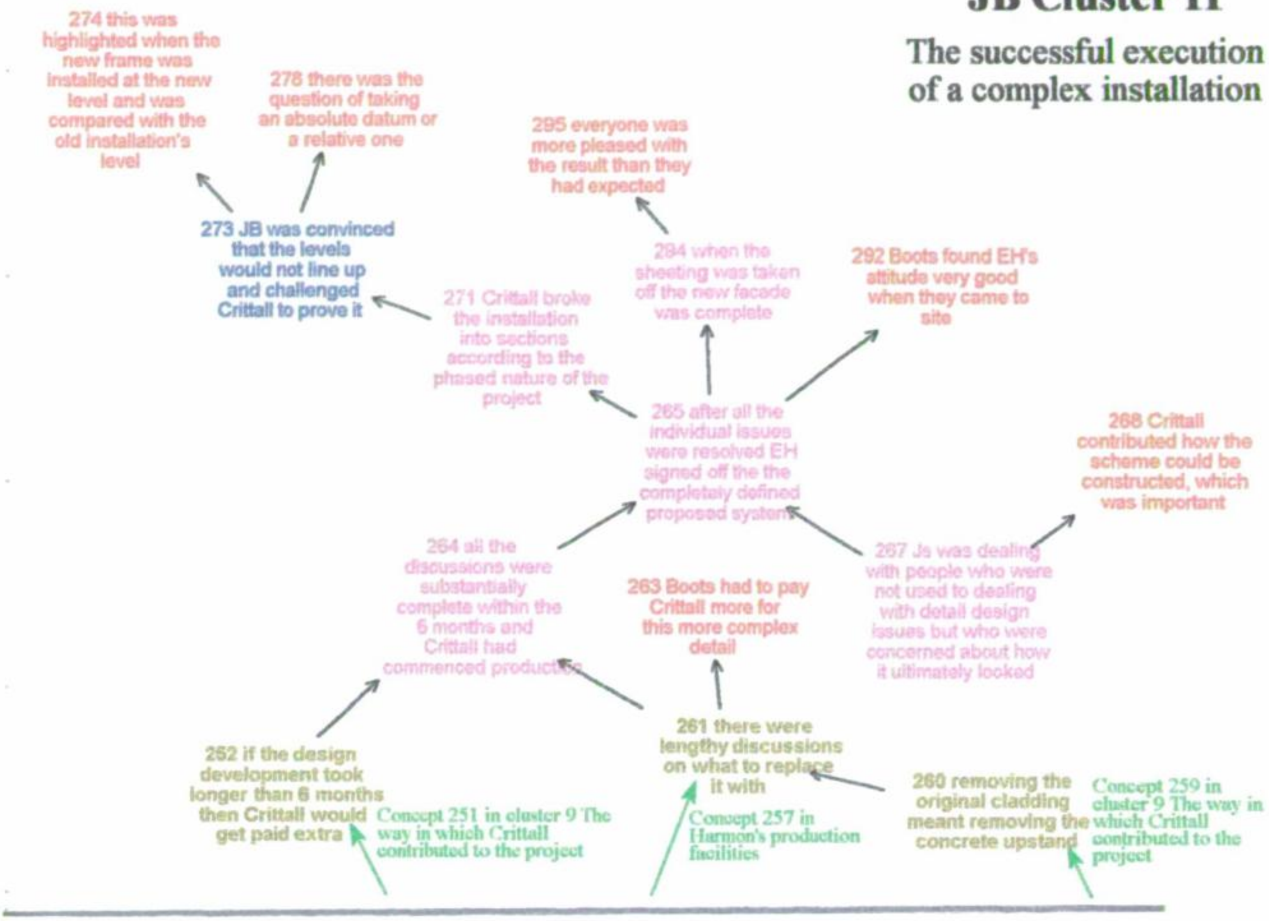


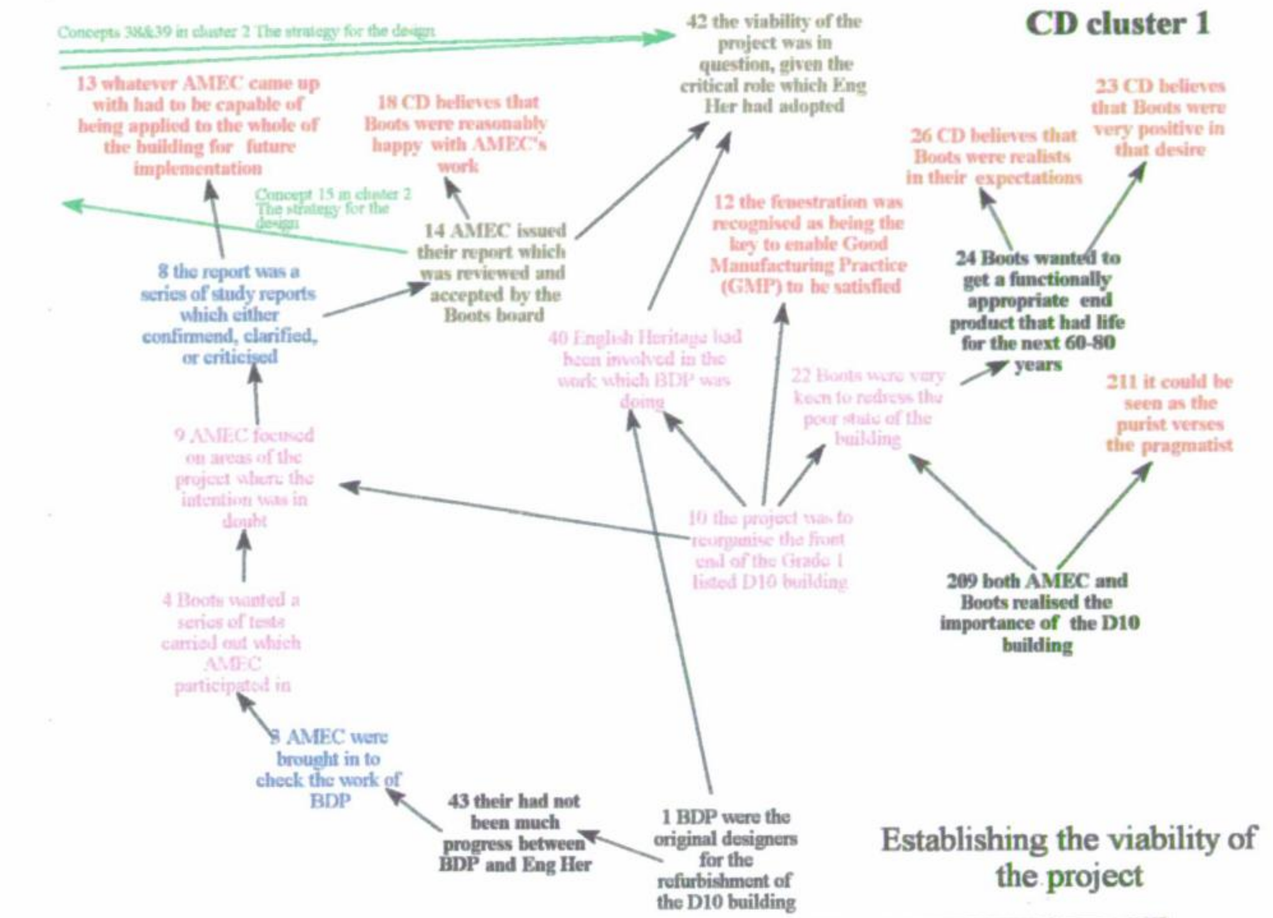

JB Cluster 9
The way in which Crittall contributed to the project
259 this was not possible as the concrete upstand had been cast after theoriginal cladding was installed
Concept 260 in cluster 11 The successful execution of a complex installation
258 what EH wanted was to retain the original concrete upstand
257 the new system had to be capable of allowing for this variation
Concept 261 in cluster 11 The successful execution of a complex installation
255 the underlying problem was the variation in dimension of the concrete upstand
Concewpt 252 in cluster 11 The successful execution of a complex installation
251 Boots came to an arrangement with Crittall that Crittall would do so much work at risk which was part of their price
249 Boots were not in a position to place an order
235 the quality of the product was vital, particularly repeatable quality
Concept 238 in cluster 10 The need for an acceptable standard of quality
236 two key areas were the sealing of the overall system
250 Boots were dependent upon EH and the planners getting satisfactory answers to their qualifications
248 this made Crittall the preferred contractor
Concepts 243 & 247 in cluster 10 The need for an acceptable standard of quality
Concept 204 in cluster 7 The transformation of the requirements to a design
230 Crittalls were innovative in their ideas and vast experience
232 discussing the history of the building with him was a fascinating experience
231 Crittall found an 85 year old designer who had worked on the original installation
233 the tender returns from both companies were very similar in price
229 there were quite detailed pretender discussions with the 2 contractors
220 the specification included details of how the job would be carried out. links to the concrete repairs
228 the contractors were asked to supply answers to all the major points
223 the specification included the cladding contractor to scaffold all the facade
226 it was one of EH's and the planners' conditions that all discussions were actually capable of being installed
219 they were sent a performance specification which was based on a normally available steel section
Concept 204 in cluster 7 The transformation of the requirements to a design
Concept 218 in cluster 8 The need for suitable trade contractors

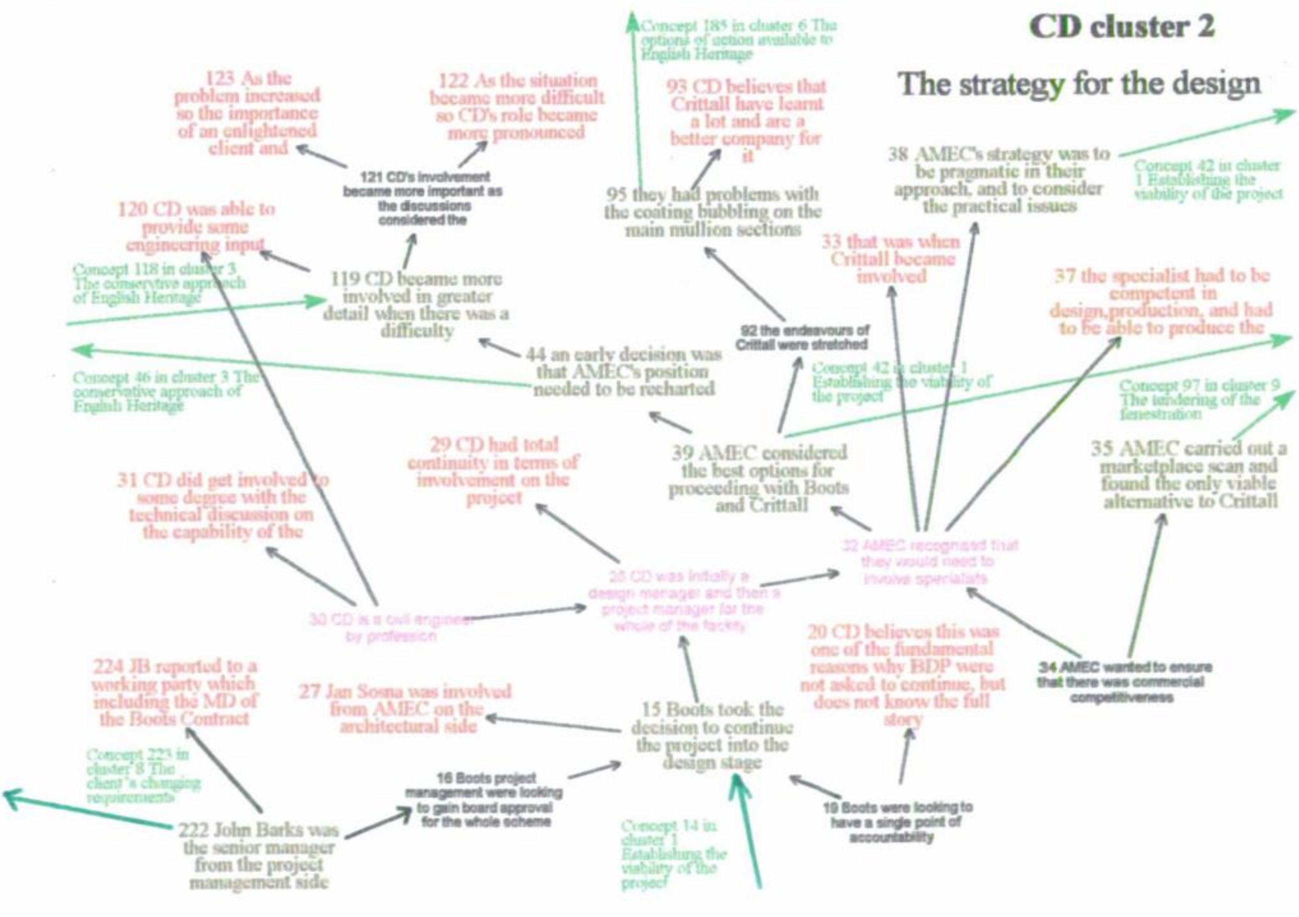

JB Cluster 10
The need for an acceptable standard of quality
290 the selected glass did not cost Boots any extra
288 the compromise solution was a mid tint
282 JB accepts that popular architectural view differs
279 there was an argument with EH about the tint of the glass
287 Boots installed different samples of glass into the building ranging from clear to highly reflective
Concept 248 in cluster 9 The way in which Crittall contributed to the project
Concept 248 in cluster 9 The way in which Crittall contributed to the project
243 Crittall's samples were of a higher quality then the other firm
247 this made Boots feel unhappy with the likely quality of the final product
280 one of the original features of the building was its apparent transparency
241 the method of galvanising was important as it was a major factor in the longevity of the system
238 the quality of the paint finish was critical to the long life of the new installation
286 both contractors built samples for EH to look at
244 the other firm had not got the size of facilities as Crittall
239 the steel frame is galvanised and then epoxy painted
Concept 236 in cluster 9 The way in which Crittall contributed to the project

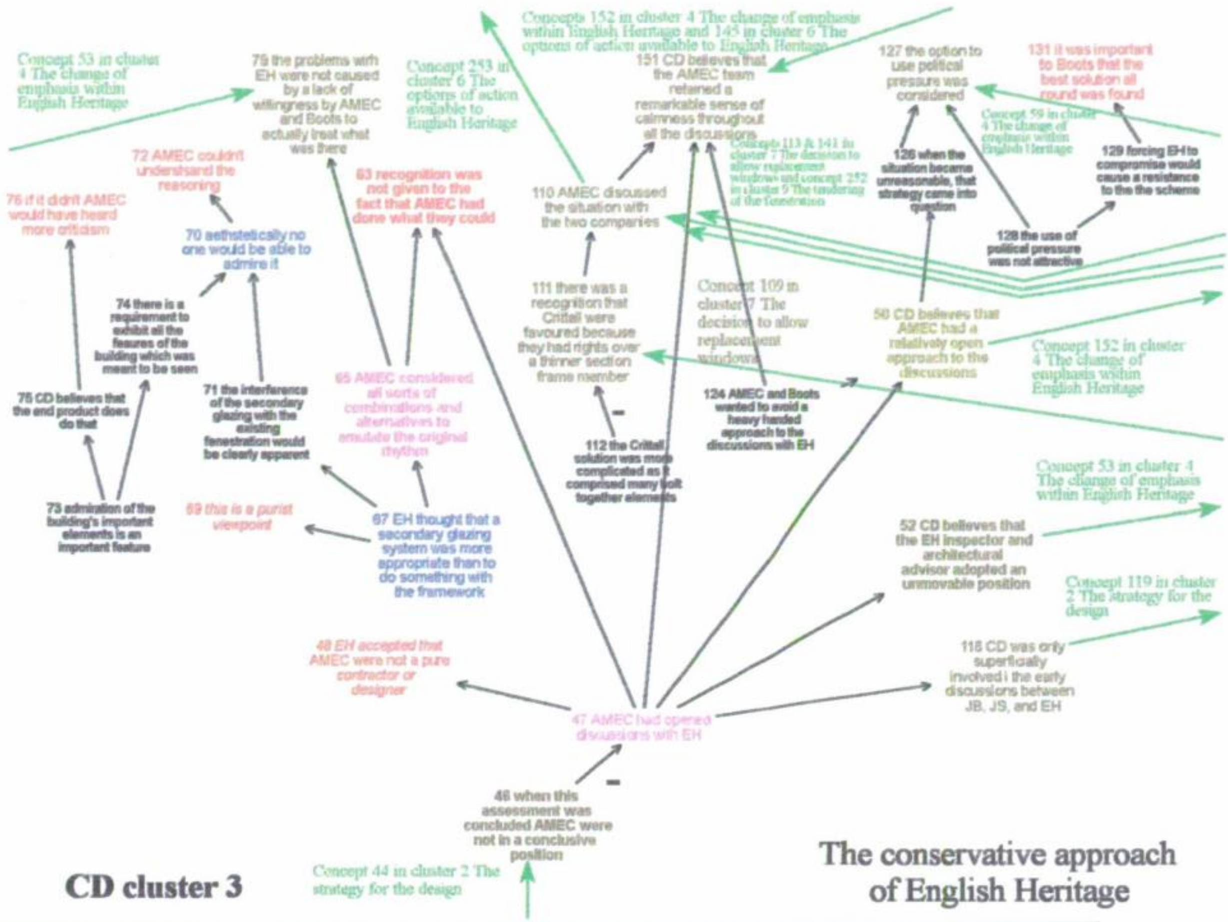
JB Cluster 11

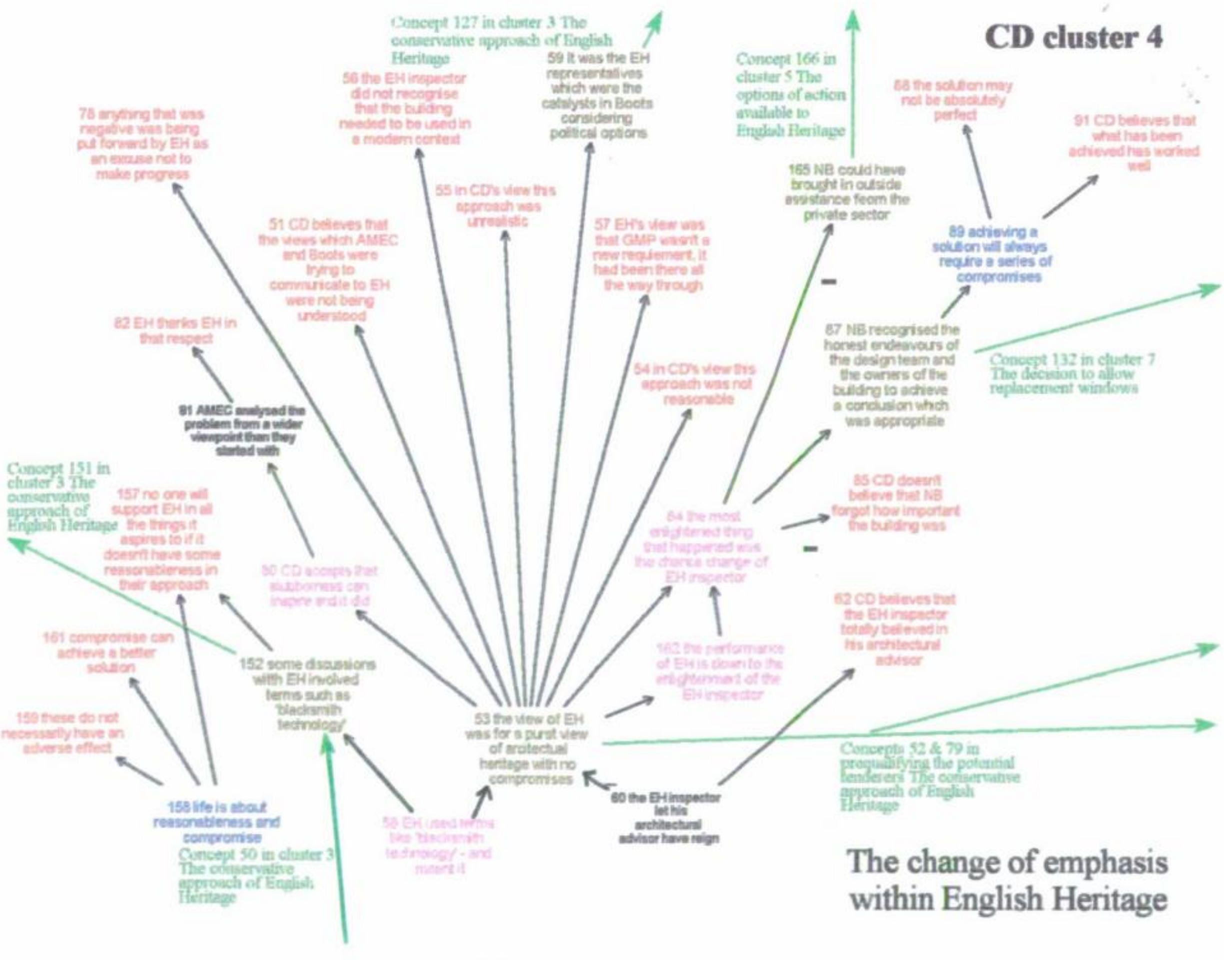
The successful execution of a complex installation




CD cluster 1
Concepts 38&39 in cluster 2 The strategy for the design
42 the viability of the project was in question, given the critical role which Eng Her had adopted
13 whatever AMEC came up with had to be capable of being applied to the whole of the building for future implementation
18 CD believes that Boots were reasonably happy with AMEC's work
23 CD believes that Boots were very positive in that desire
26 CD believes that Boots were realists in their expectations
Concept 15 in cluster 2 The strategy for the design
14 AMEC issued their report which was reviewed and accepted by the Boots board
12 the fenestration was recognised as being the key to enable Good Manufacturing Practice (GMP) to be satisfied
24 Boots wanted to get a functionally appropriate end product that had life for the next 60-80 years
8 the report was a series of study reports which either confirmend, clarified, or criticised
40 English Heritage had been involved in the work which BDP was doing
22 Boots were very keen to redress the poor state of the building
211 it could be seen as the purist verses the pragmatist
9 AMEC focused on areas of the project where the intention was in doubt
10 the project was to reorganise the front end of the Grade 1 listed D10 building
209 both AMEC and Boots realised the importance of the D10 building
4 Boots wanted a series of tests carried out which AMEC participated in
3 AMEC were brought in to check the work of BDP
43 their had not been much progress between BDP and Eng Her
1 BDP were the original designers for the refurbishment of the D10 building
Establishing the viability of the project


CD cluster 2
The strategy for the design
Concept 185 in cluster 6 The options of action available to English Heritage
123 As the problem increased so the importance of an enlightened client and
122 As the situation became more difficult so CD's role became more pronounced
93 CD believes that Crittall have learnt a lot and are a better company for it
121 CD's involvement became more important as the discussions considered the
38 AMEC's strategy was to be pragmatic in their approach, and to consider the practical issues
Concept 42 in cluster 1 Establishing the viability of the project
120 CD was able to provide some engineering input
95 they had problems with the coating bubbling on the main mullion sections
33 that was when Crittall became involved
Concept 118 in cluster 3 The conservative approach of English Heritage
119 CD became more involved in greater detail when there was a difficulty
37 the specialist had to be competent in design,production, and had to be able to produce the
92 the endeavours of Crittall were stretched
44 an early decision was that AMEC's position needed to be recharted
Concept 46 in cluster 3 The conservative approach of English Heritage
Concept 42 in cluster 1 Establishing the viability of the project
Concept 97 in cluster 9 The tendering of the fenestration
29 CD had total continuity in terms of involvement on the project
39 AMEC considered the best options for proceeding with Boots and Crittall
35 AMEC carried out a marketplace scan and found the only viable alternative to Crittall
31 CD did get involved to some degree with the technical discussion on the capability of the
32 AMEC recognised that they would need to involve specialists
28 CD was initially a design manager and then a project manager for the whole of the facility
30 CD is a civil engineer by profession
20 CD believes this was one of the fundamental reasons why BDP were not asked to continue, but does not know the full story
34 AMEC wanted to ensure that there was commercial competitiveness
224 JB reported to a working party which including the MD of the Boots Contract
27 Jan Sosna was involved from AMEC on the architectural side
15 Boots took the decision to continue the project into the design stage
Concept 223 in cluster 8 The client's changing requirements
16 Boots project management were looking to gain board approval for the whole scheme
19 Boots were looking to have a single point of accountability
222 John Barks was the senior manager from the project management side
Concept 14 in cluster 1 Establishing the viability of the project

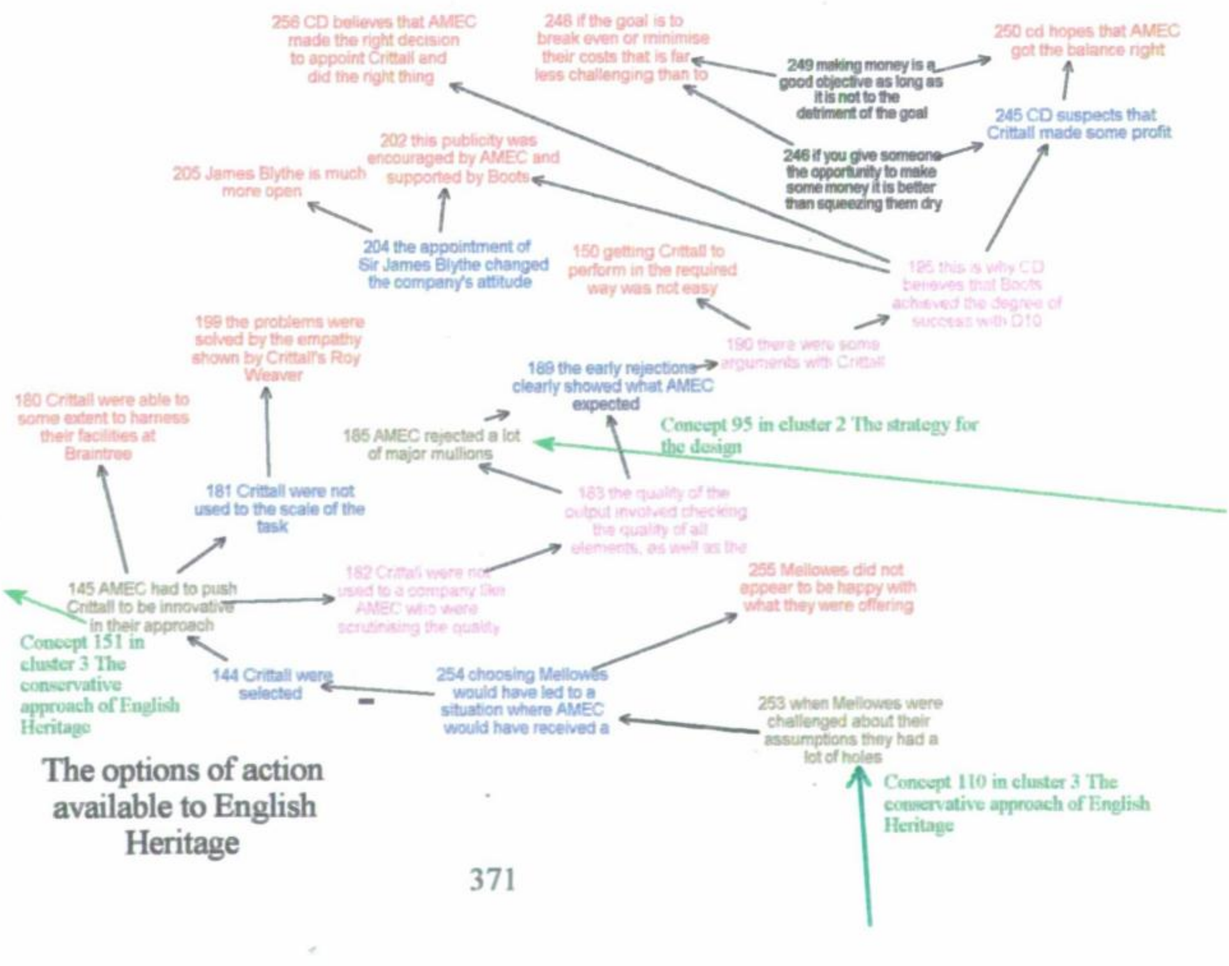

CD cluster 3
The conservative approach of English Heritage
Concept 53 in cluster 4 The change of emphasis within English Heritage
75 the problems with EH were not caused by a lack of willingness by AMEC and Boots to actually treat what was there
Concept 253 in cluster 6 The options of action available to English Heritage
Concepts 152 in cluster 4 The change of emphasis within English Heritage and 145 in cluster 6 The options of action available to English Heritage
151 CD believes that the AMEC team retained a remarkable sense of calmness throughout all the discussions
127 the option to use political pressure was considered
131 it was important to Boots that the best solution all round was found
72 AMEC couldn't understand the reasoning
76 if it didn't AMEC would have heard more criticism
70 aesthetically no one would be able to admire it
63 recognition was not given to the fact that AMEC had done what they could
110 AMEC discussed the situation with the two companies
Concepts 113 & 141 in cluster 7 The decision to allow replacement windows and concept 252 in cluster 9 The tendering of the fenestration
126 when the situation became unreasonable, that strategy came into question
129 forcing EH to compromise would cause a resistance to the the scheme
128 the use of political pressure was not attractive
74 there is a requirement to exhibit all the features of the building which was meant to be seen
111 there was a recognition that Crittall were favoured because they had rights over a thinner section frame member
Concept 109 in cluster 7 The decision to allow replacement windows
56 CD believes that AMEC had a relatively open approach to the discussions
Concept 152 in cluster 4 The change of emphasis within English Heritage
75 CD believes that the end product does do that
71 the interference of the secondary glazing with the existing fenestration would be clearly apparent
65 AMEC considered all sorts of combinations and alternatives to emulate the original rhythm
124 AMEC and Boots wanted to avoid a heavy handed approach to the discussions with EH
112 the Crittall solution was more complicated as it comprised many bolt together elements
Concept 53 in cluster 4 The change of emphasis within English Heritage
73 admiration of the building's important elements is an important feature
69 this is a purist viewpoint
67 EH thought that a secondary glazing system was more appropriate than to do something with the framework
52 CD believes that the EH inspector and architectural advisor adopted an unmovable position
Concept 119 in cluster 2 The strategy for the design
48 EH accepted that AMEC were not a pure contractor or designer
118 CD was only superficially involved i the early discussions between JB, JS, and EH
47 AMEC had opened discussions with EH
46 when this assessment was concluded AMEC were not in a conclusive position
Concept 44 in cluster 2 The strategy for the design


CD cluster 4
The change of emphasis within English Heritage
Concept 127 in cluster 3 The conservative approach of English Heritage
56 the EH inspector did not recognise that the building needed to be used in a modern context
59 it was the EH representatives which were the catalysts in Boots considering political options
Concept 166 in cluster 5 The options of action available to English Heritage
88 the solution may not be absolutely perfect
91 CD believes that what has been achieved has worked well
78 anything that was negative was being put forward by EH as an excuse not to make progress
55 in CD's view this approach was unrealistic
165 NB could have brought in outside assistance from the private sector
51 CD believes that the views which AMEC and Boots were trying to communicate to EH were not being understood
57 EH's view was that GMP wasn't a new requirement, it had been there all the way through
89 achieving a solution will always require a series of compromises
82 EH thanks EH in that respect
87 NB recognised the honest endeavours of the design team and the owners of the building to achieve a conclusion which was appropriate
Concept 132 in cluster 7 The decision to allow replacement windows
54 in CD's view this approach was not reasonable
81 AMEC analysed the problem from a wider viewpoint than they started with
Concept 151 in cluster 3 The conservative approach of English Heritage
157 no one will support EH in all the things it aspires to if it doesn't have some reasonableness in their approach
85 CD doesn't believe that NB forgot how important the building was
84 the most enlightened thing that happened was the chance change of EH inspector
80 CD accepts that stubborness can inspire and it did
161 compromise can achieve a better solution
152 some discussions with EH involved terms such as 'blacksmith technology'
162 the performance of EH is down to the enlightenment of the EH inspector
62 CD believes that the EH inspector totally believed in his architectural advisor
159 these do not necessarily have an adverse effect
53 the view of EH was for a purist view of architectural heritage with no compromises
Concepts 52 & 79 in prequalifying the potential tenderers The conservative approach of English Heritage
158 life is about reasonableness and compromise
Concept 50 in cluster 3 The conservative approach of English Heritage
58 EH used terms like 'blacksmith technology' - and meant it
60 the EH inspector let his architectural advisor have reign

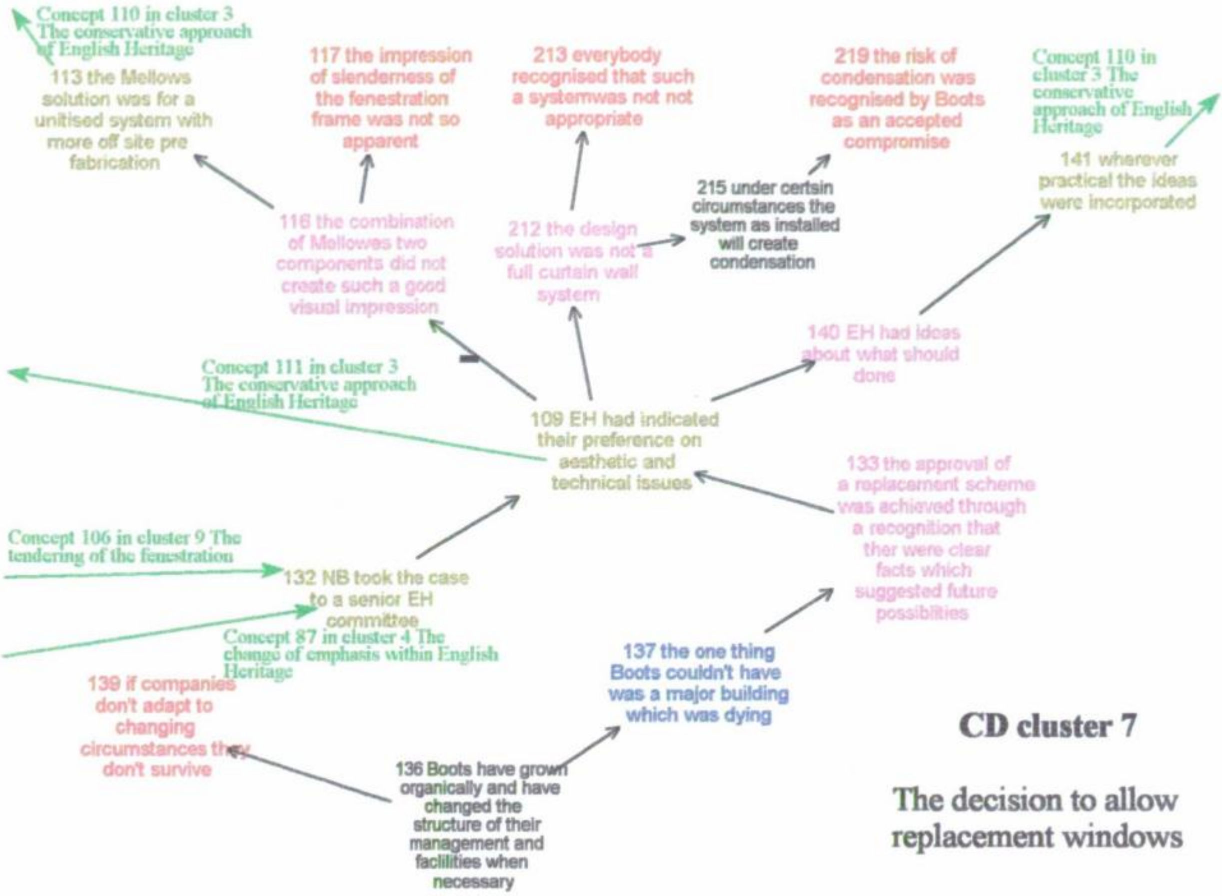
CD cluster 5

The options of action available to English Heritage

CD cluster 6

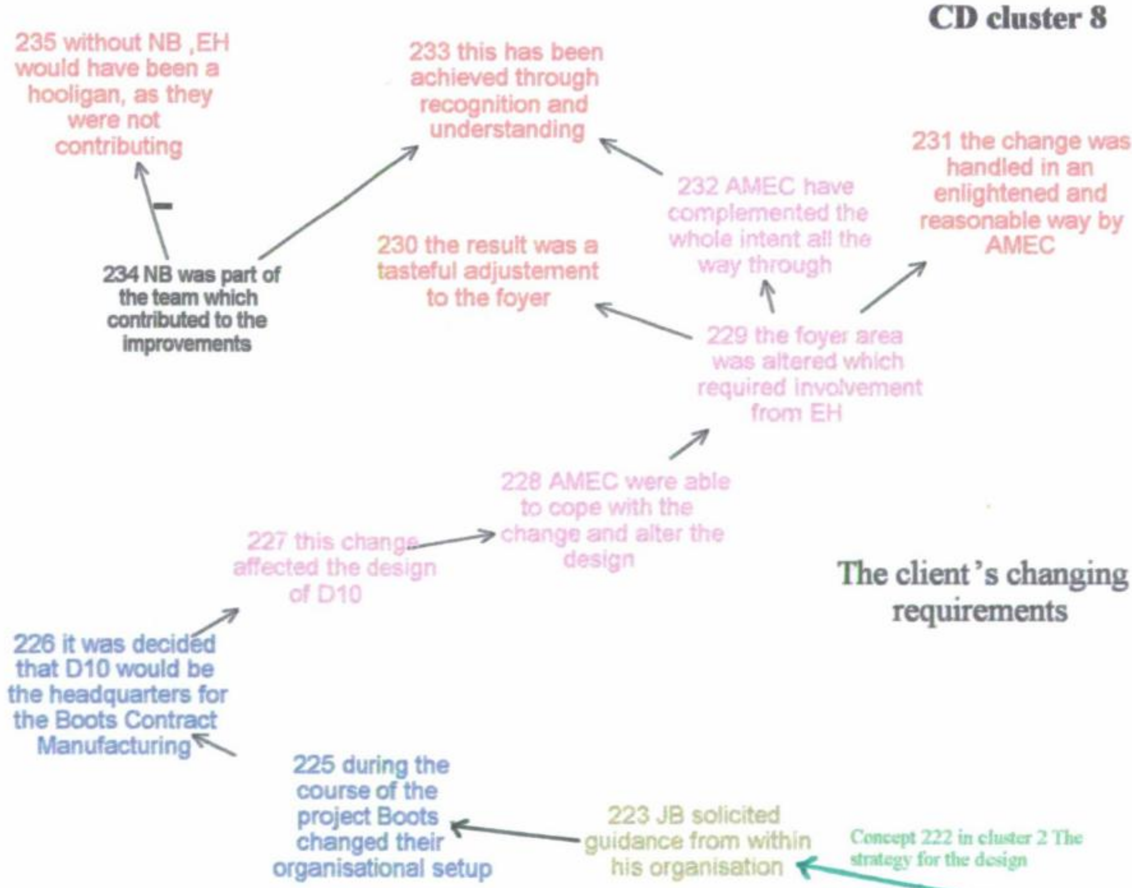


The options of action available to English Heritage



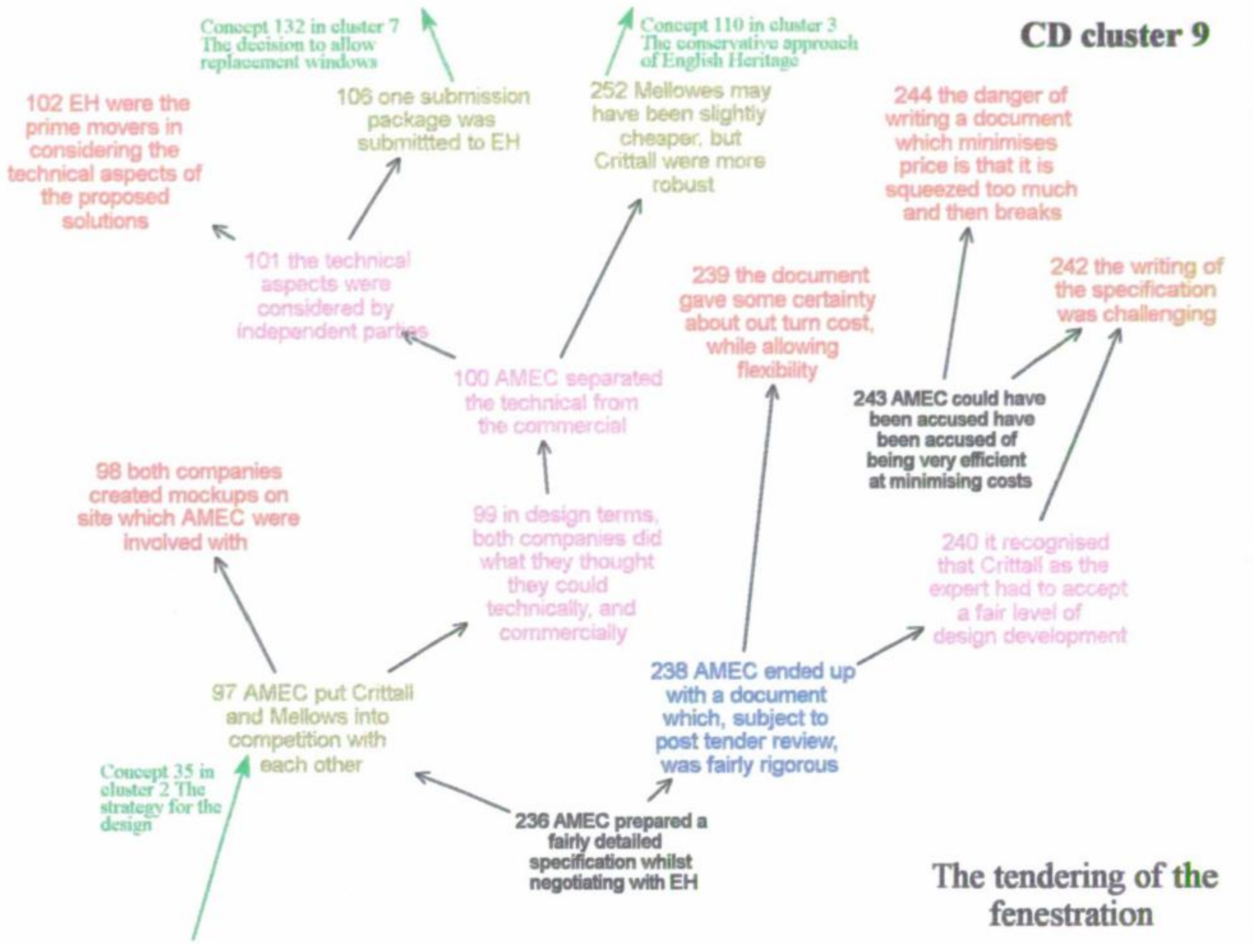
CD cluster 7

The decision to allow replacement windows



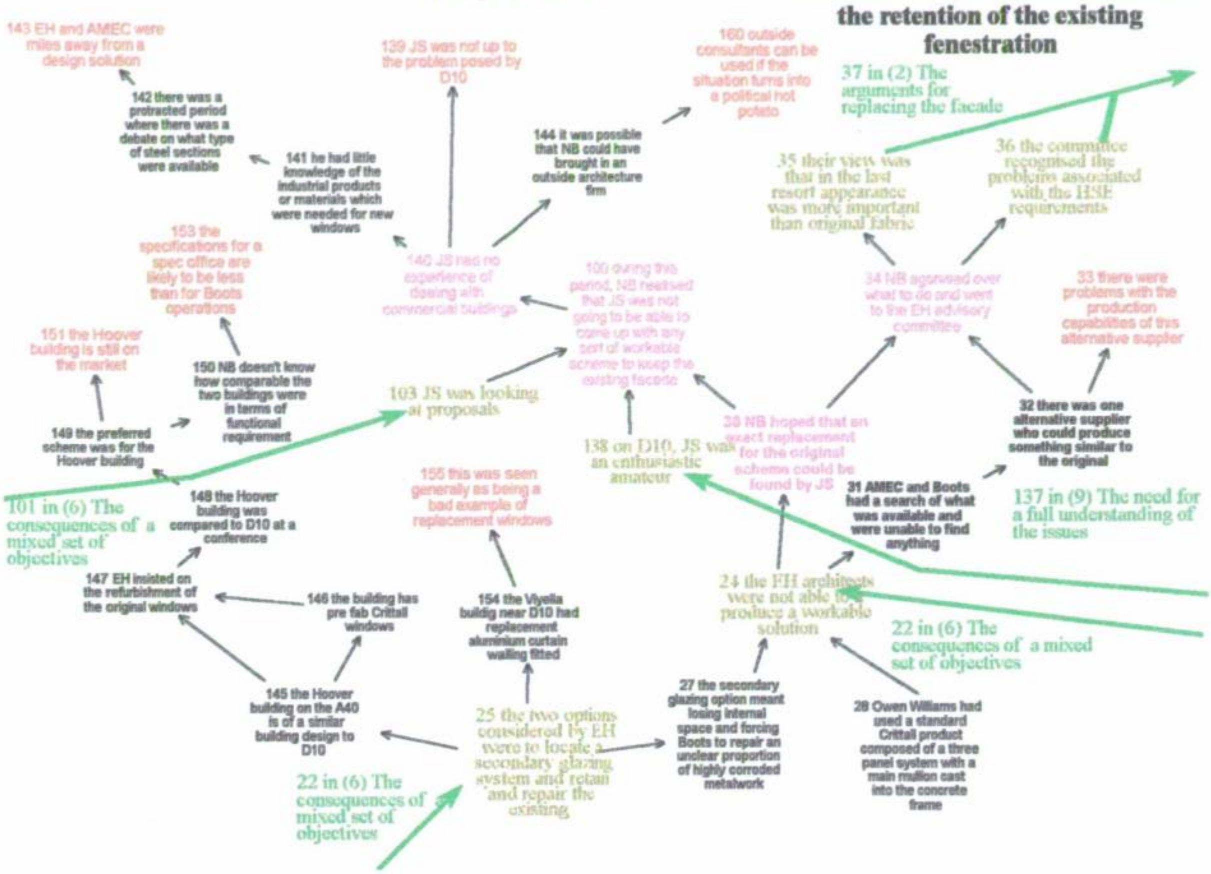
CD cluster 8

The client's changing requirements


CD cluster 9
Concept 132 in cluster 7 The decision to allow replacement windows
Concept 110 in cluster 3 The conservative approach of English Heritage
102 EH were the prime movers in considering the technical aspects of the proposed solutions
106 one submission package was submittted to EH
252 Mellowes may have been slightly cheaper, but Crittall were more robust
244 the danger of writing a document which minimises price is that it is squeezed too much and then breaks
101 the technical aspects were considered by independent parties
239 the document gave some certainty about out turn cost, while allowing flexibility
242 the writing of the specification was challenging
100 AMEC separated the technical from the commercial
243 AMEC could have been accused have been accused of being very efficient at minimising costs
98 both companies created mockups on site which AMEC were involved with
99 in design terms, both companies did what they thought they could technically, and commercially
240 it recognised that Crittall as the expert had to accept a fair level of design development
97 AMEC put Crittall and Mellows into competition with each other
238 AMEC ended up with a document which, subject to post tender review, was fairly rigorous
Concept 35 in cluster 2 The strategy for the design
236 AMEC prepared a fairly detailed specification whilst negotiating with EH
The tendering of the fenestration

NB Cluster 1

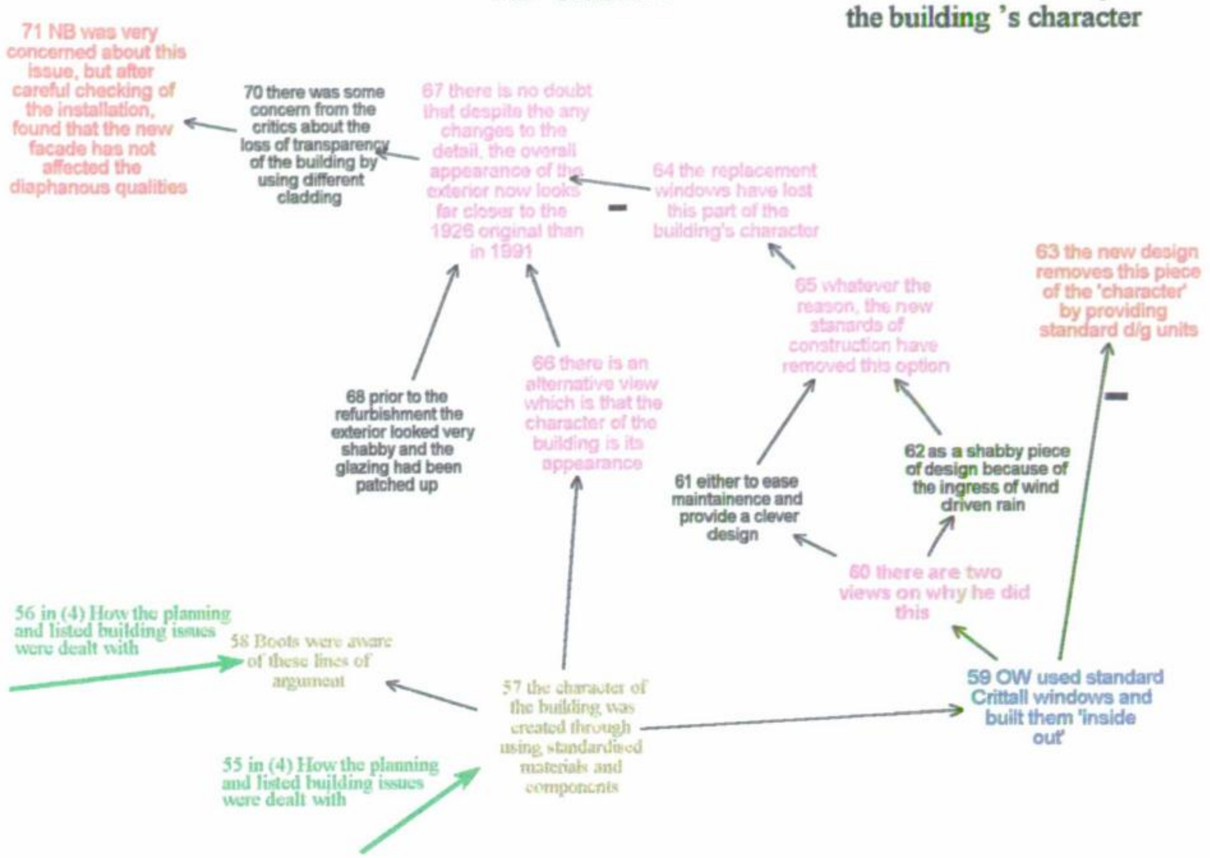
The failure of a workable scheme for the retention of the existing fenestration



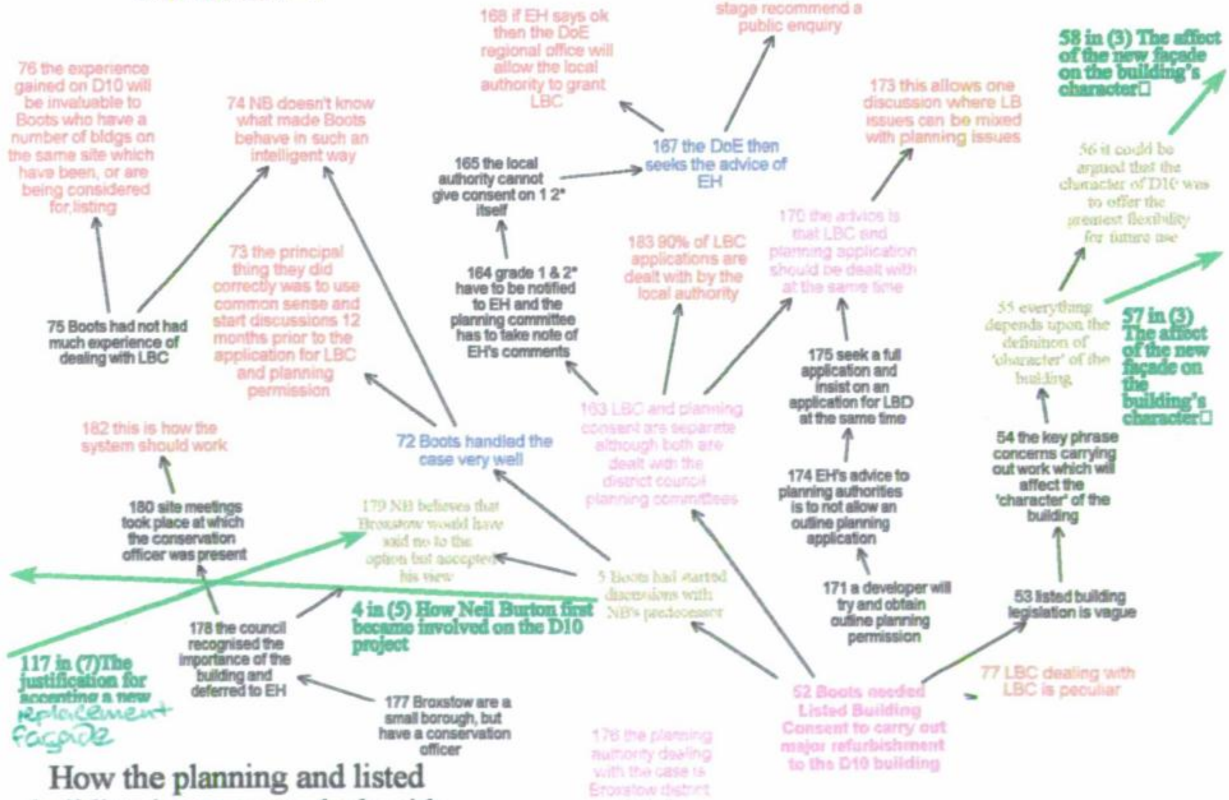
NB Cluster 2

The arguments for replacing the fa çade

NB Cluster 3 **The affect of the new fa çade on the building 's character**

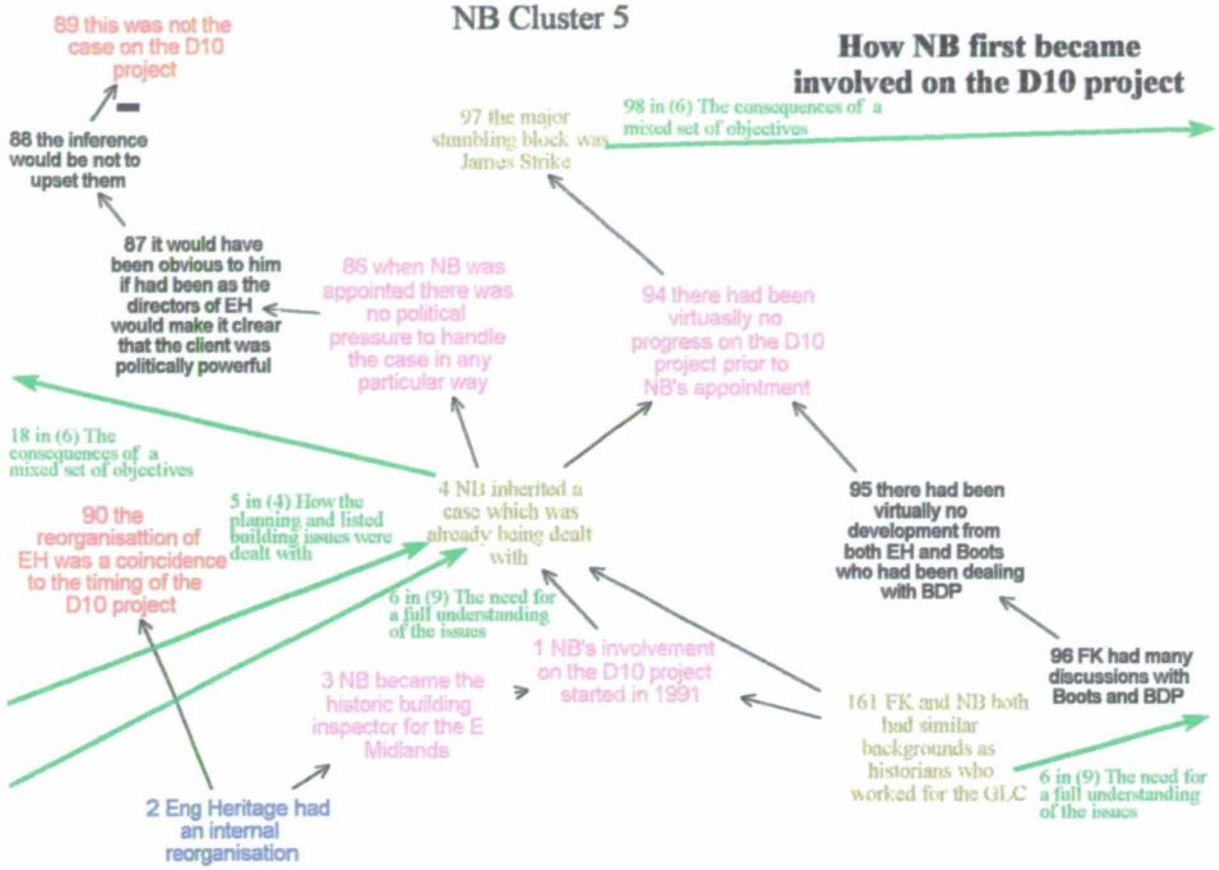


NB Cluster 4

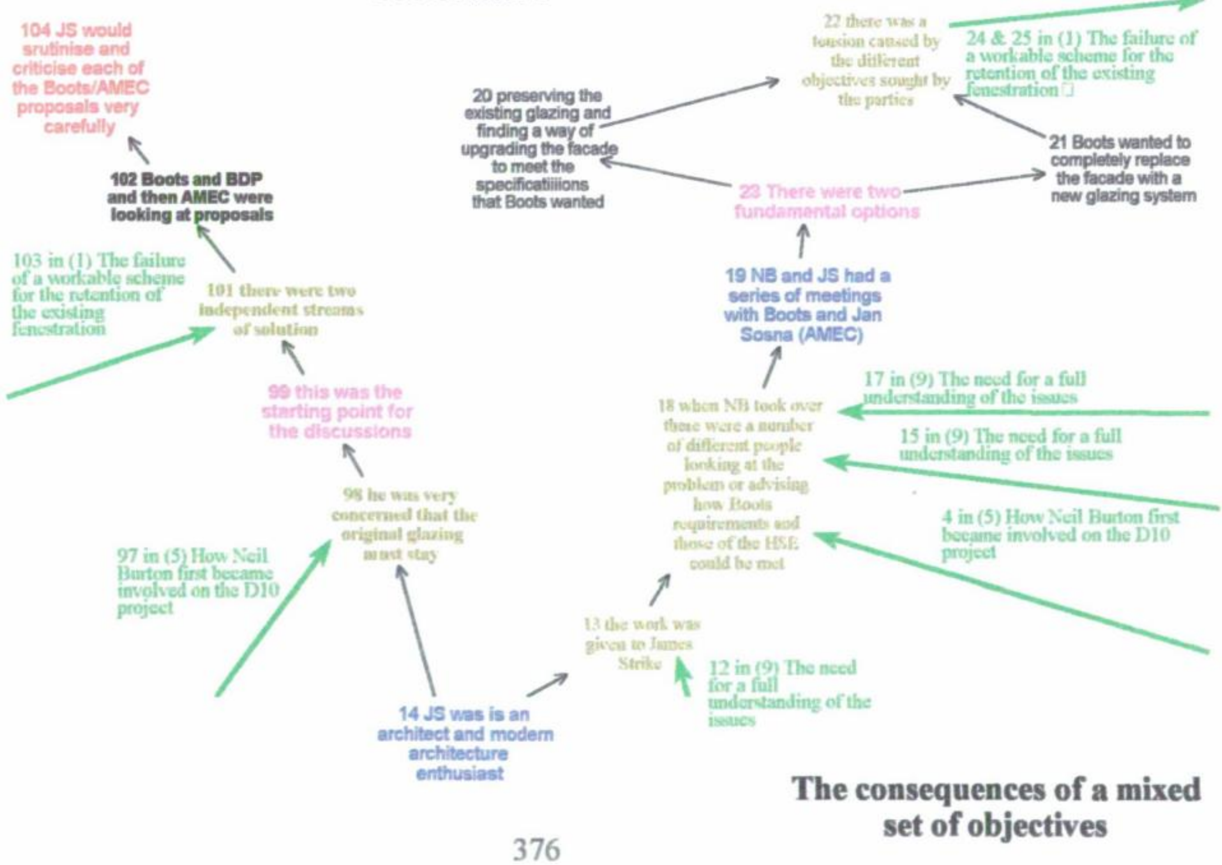


How the planning and listed building issues were dealt with

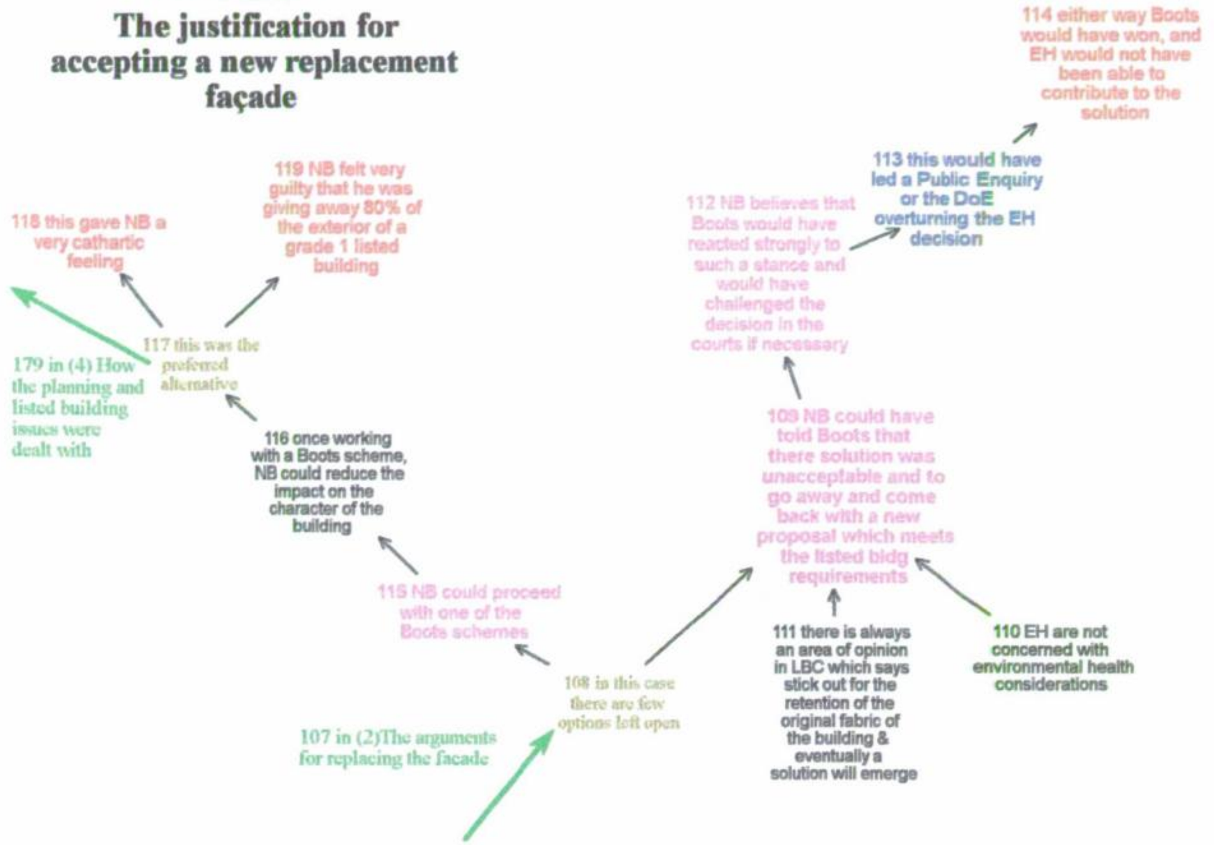
NB Cluster 5



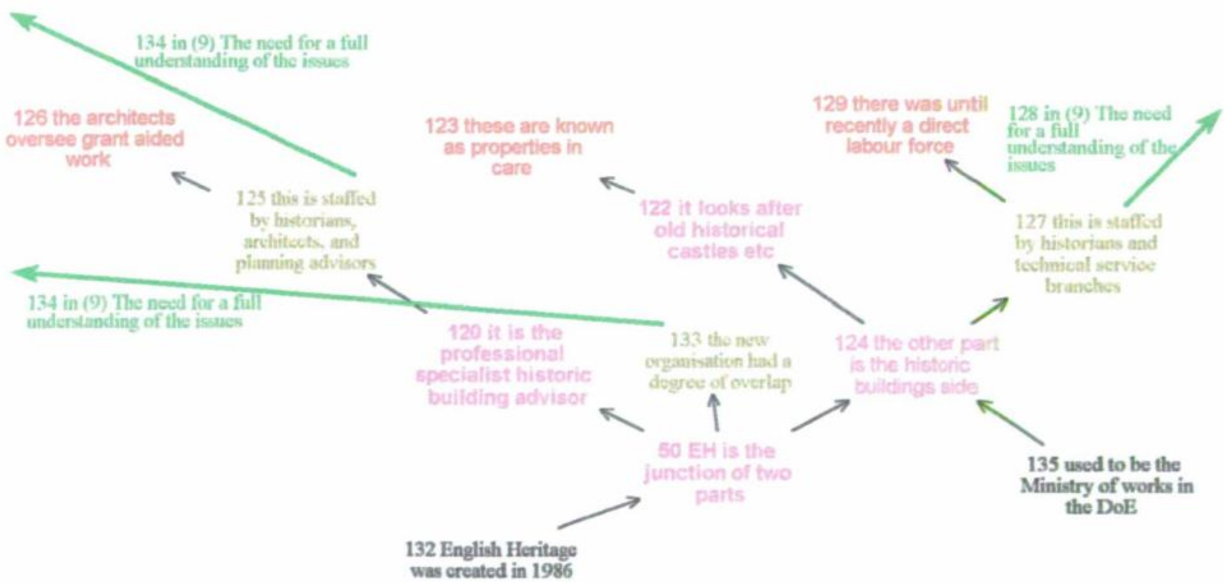
NB Cluster 6



NB Cluster 7
The justification for accepting a new replacement façade

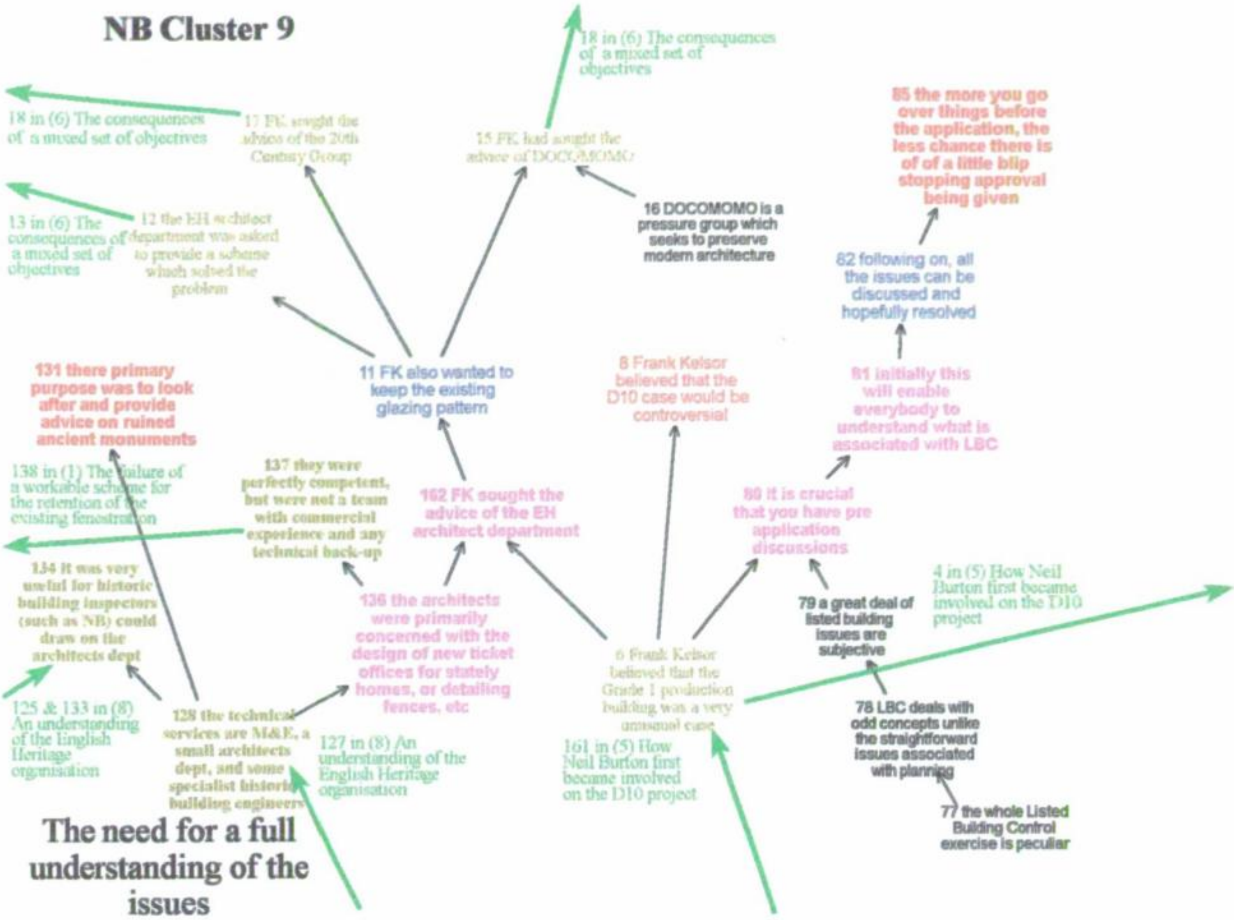


NB Cluster 8



An understanding of the English Heritage organisation

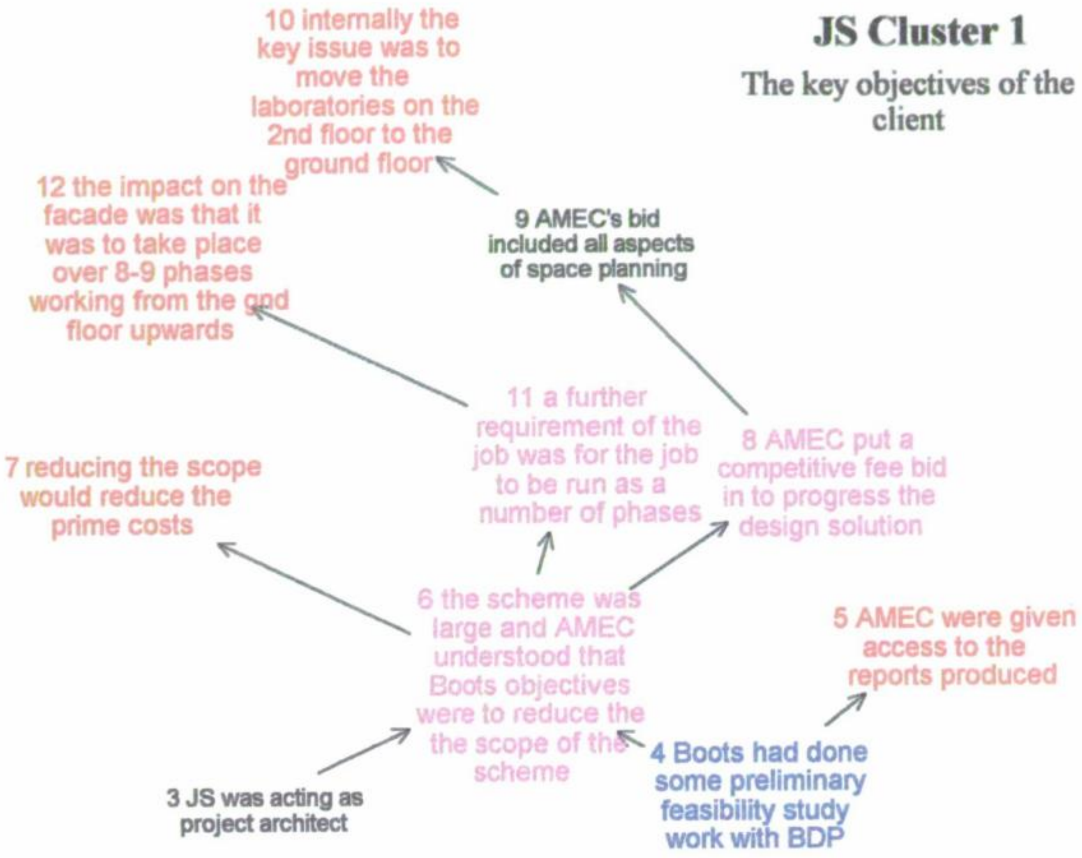
NB Cluster 9



18 in (6) The consequences of a mixed set of objectives
18 in (6) The consequences of a mixed set of objectives
17 FK sought the advice of the 20th Century Group
15 FK had sought the advice of DOCOMOMO
16 DOCOMOMO is a pressure group which seeks to preserve modern architecture
85 the more you go over things before the application, the less chance there is of of a little blip stopping approval being given
13 in (6) The consequences of a mixed set of objectives
12 the EH architect department was asked to provide a scheme which solved the problem
82 following on, all the issues can be discussed and hopefully resolved
131 there primary purpose was to look after and provide advice on ruined ancient monuments
11 FK also wanted to keep the existing glazing pattern
8 Frank Kelsor believed that the D10 case would be controversial
81 initially this will enable everybody to understand what is associated with LBC
138 in (1) The failure of a workable scheme for the retention of the existing fenestration
137 they were perfectly competent, but were not a team with commercial experience and any technical back-up
162 FK sought the advice of the EH architect department
80 it is crucial that you have pre application discussions
134 it was very useful for historic building inspectors (such as NB) could draw on the architects dept
136 the architects were primarily concerned with the design of new ticket offices for stately homes, or detailing fences, etc
4 in (5) How Neil Burton first became involved on the D10 project
79 a great deal of listed building issues are subjective
6 Frank Kelsor believed that the Grade 1 production building was a very unusual case
125 & 133 in (8) An understanding of the English Heritage organisation
128 the technical services are M&E, a small architects dept, and some specialist historic building engineers
127 in (8) An understanding of the English Heritage organisation
161 in (5) How Neil Burton first became involved on the D10 project
78 LBC deals with odd concepts unlike the straightforward issues associated with planning
77 the whole Listed Building Control exercise is peculiar
The need for a full understanding of the issues

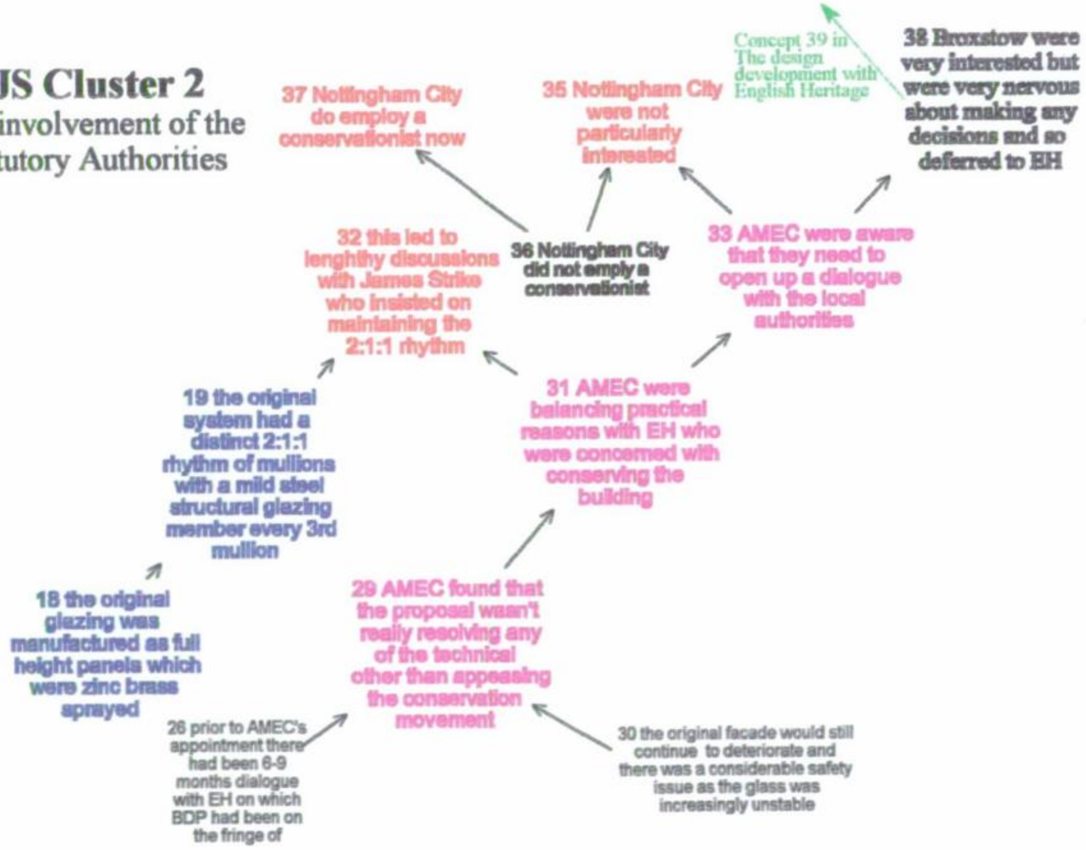
JS Cluster 1

The key objectives of the client

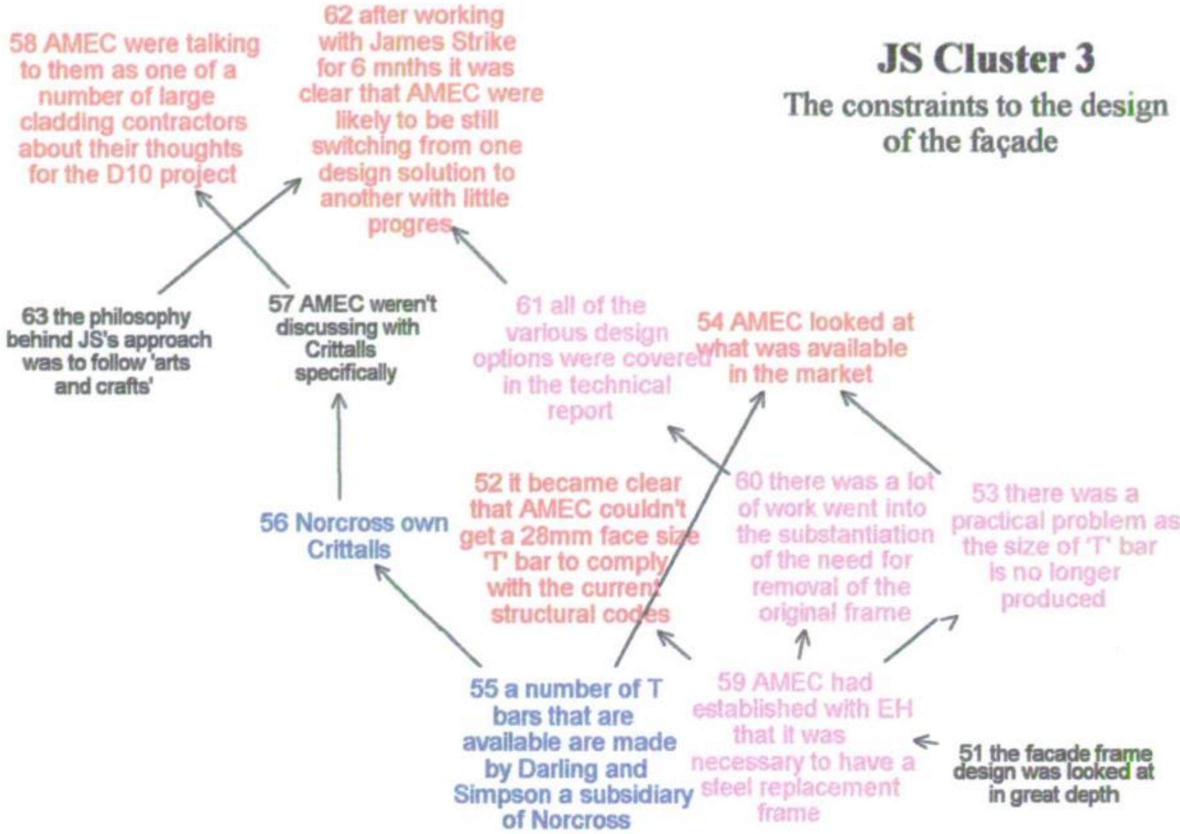


JS Cluster 2

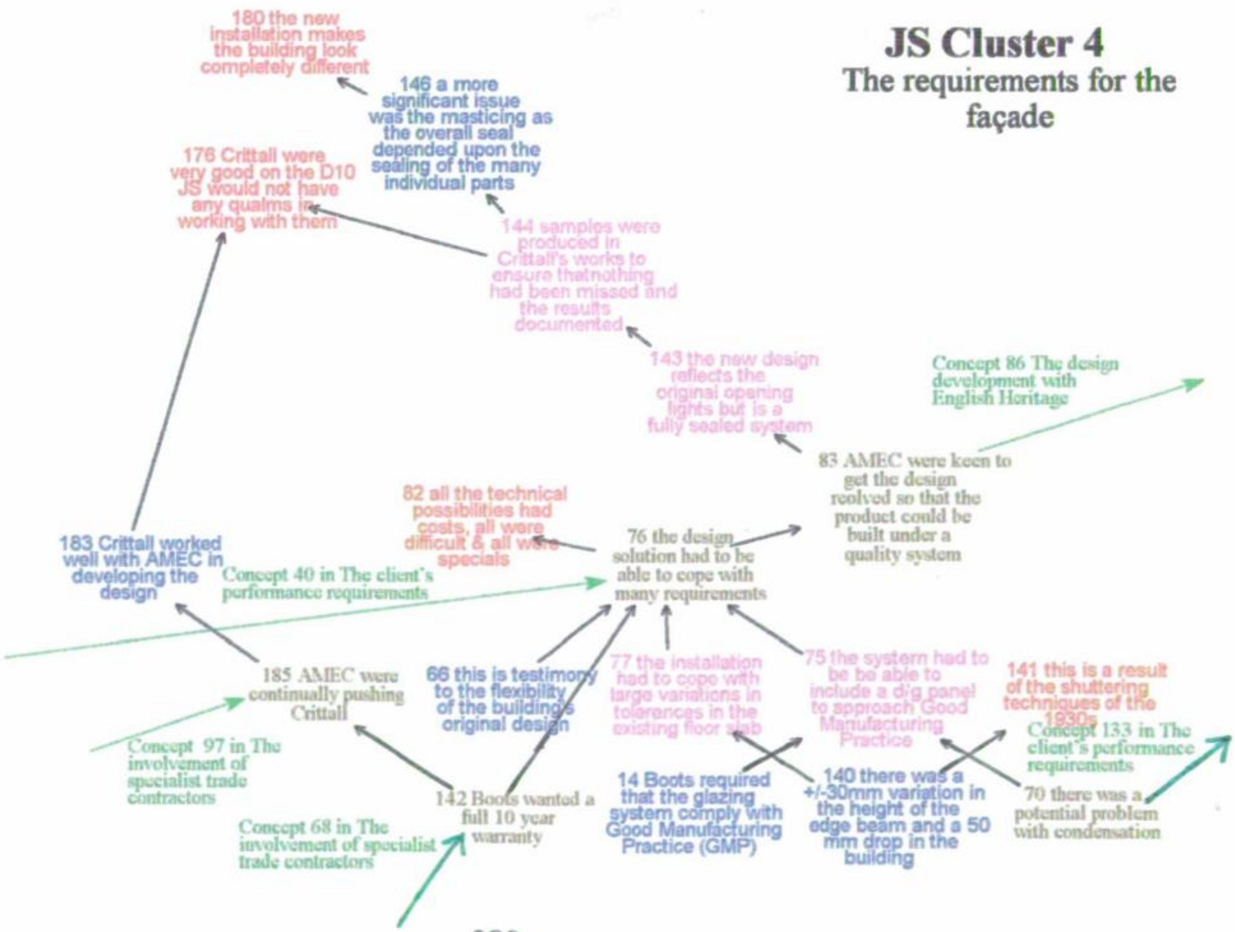
The involvement of the Statutory Authorities



JS Cluster 3
The constraints to the design of the façade

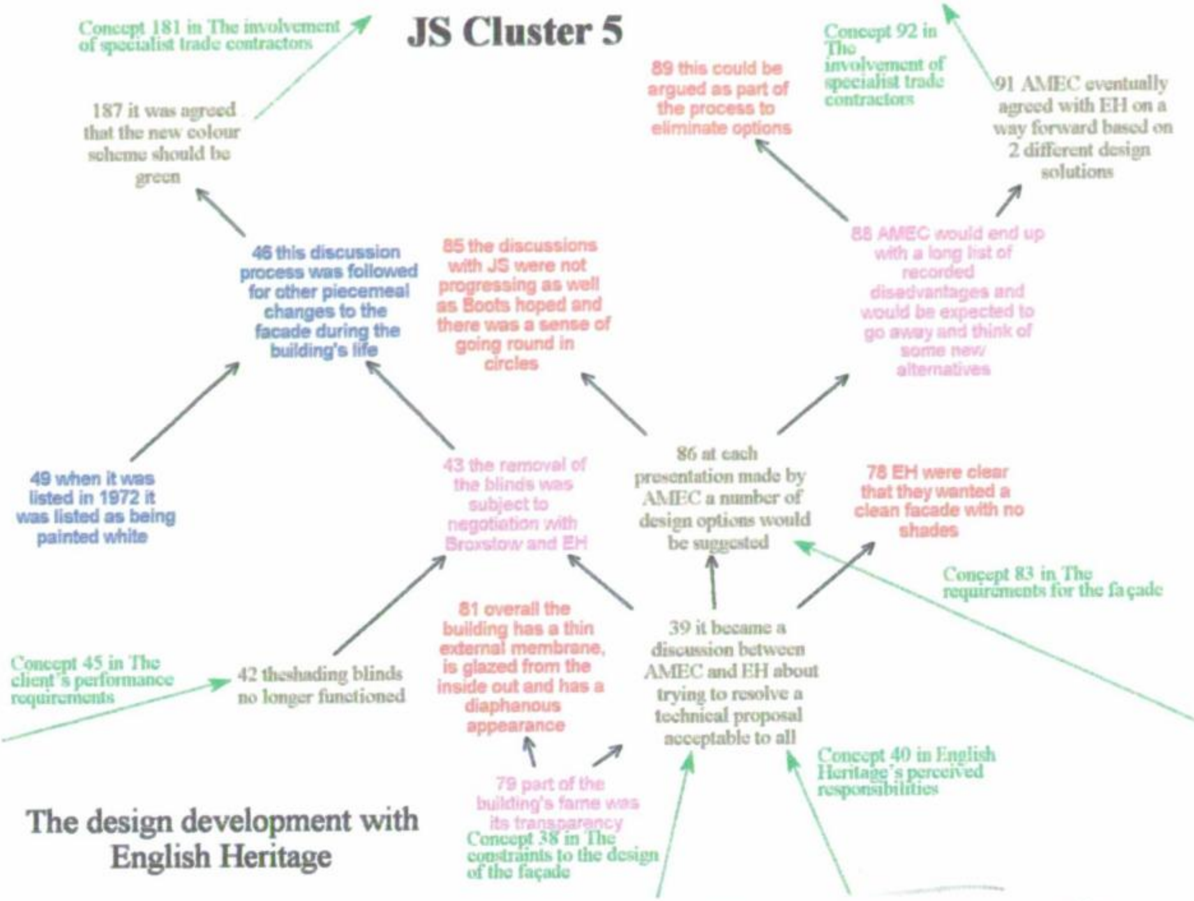


JS Cluster 4
The requirements for the façade



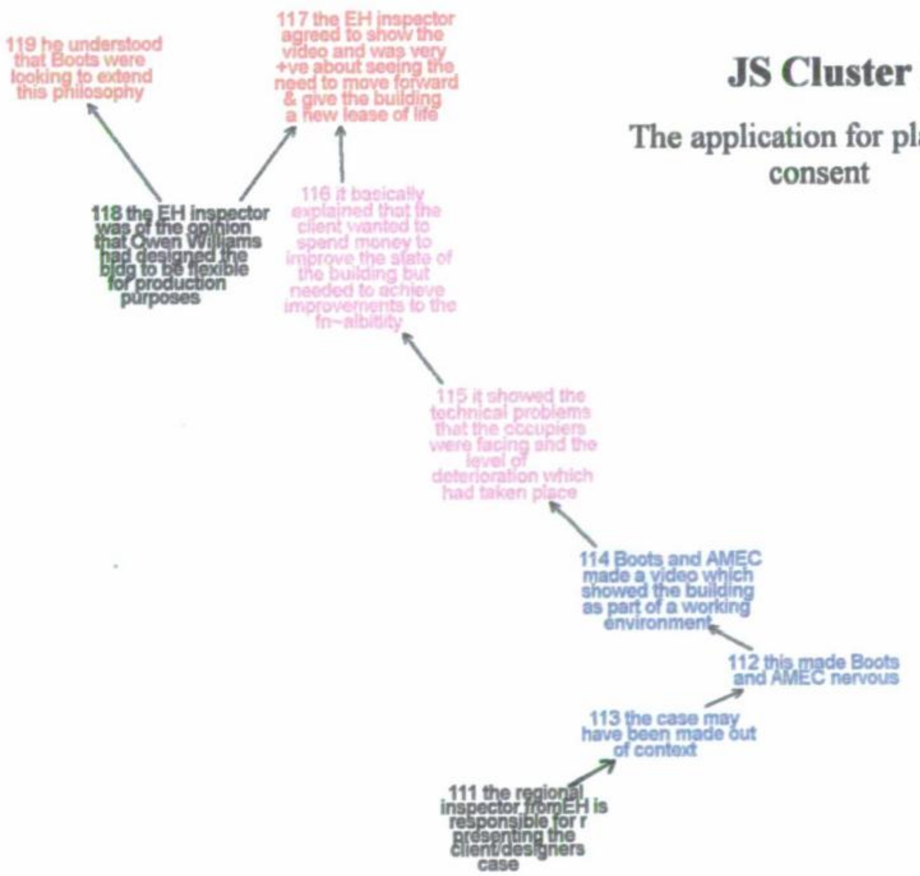
JS Cluster 5

The design development with English Heritage

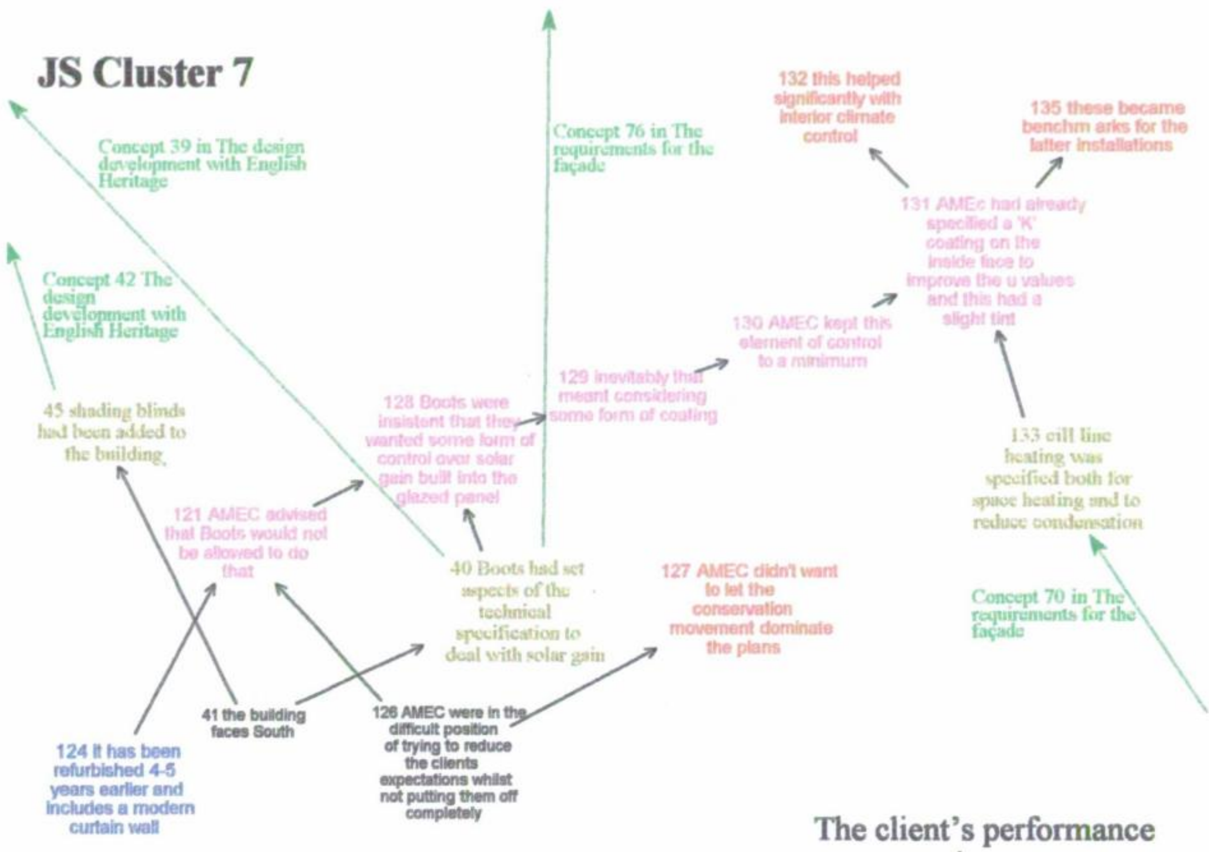


JS Cluster 6

The application for planning consent



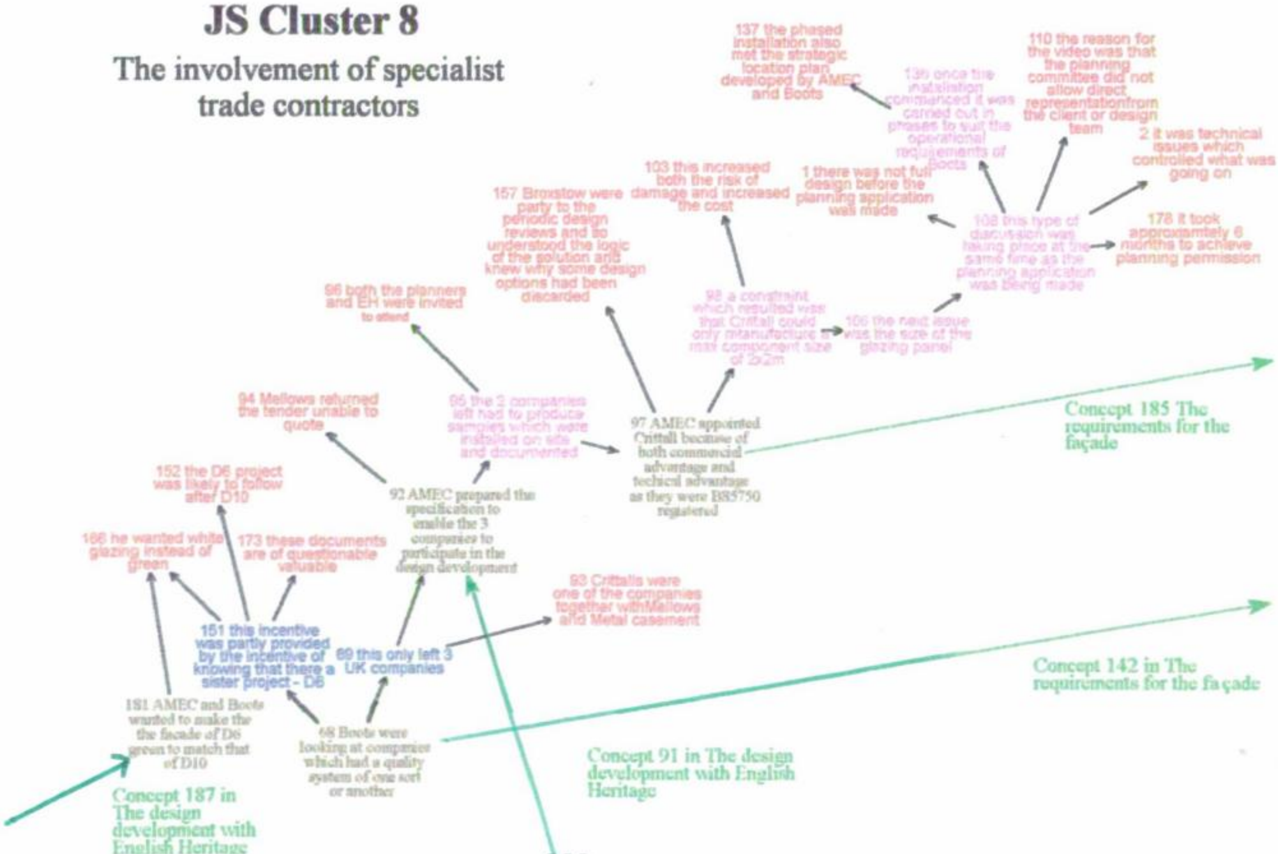
JS Cluster 7



The client's performance requirements

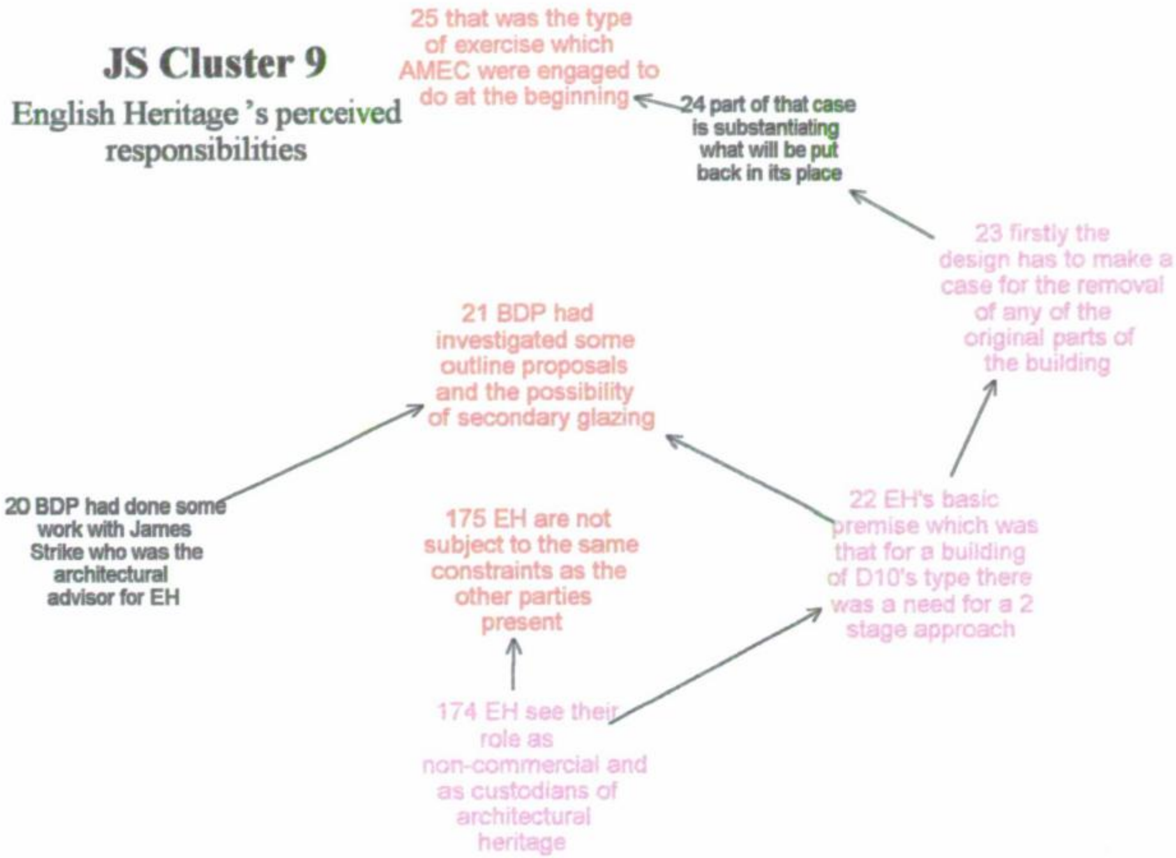
JS Cluster 8

The involvement of specialist trade contractors

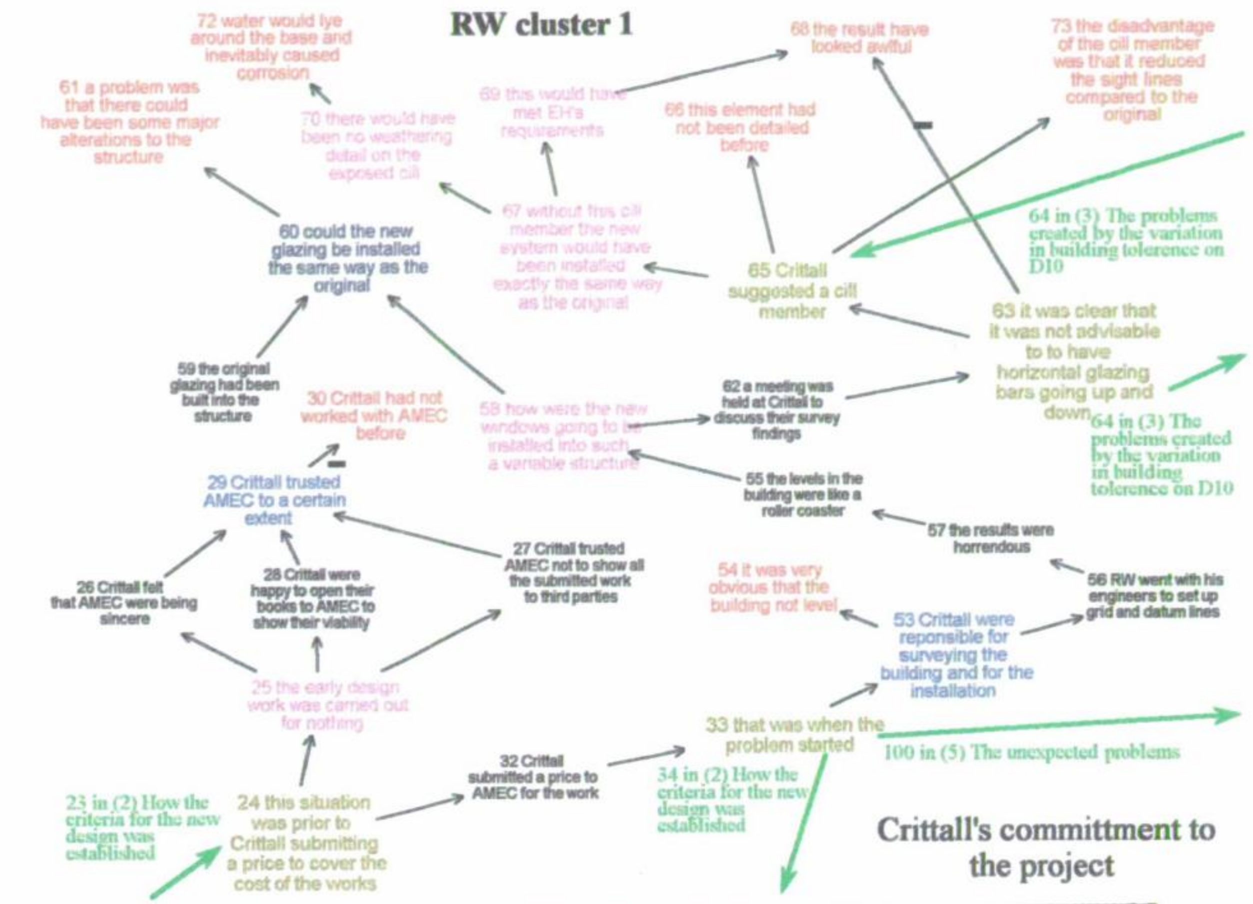


JS Cluster 9

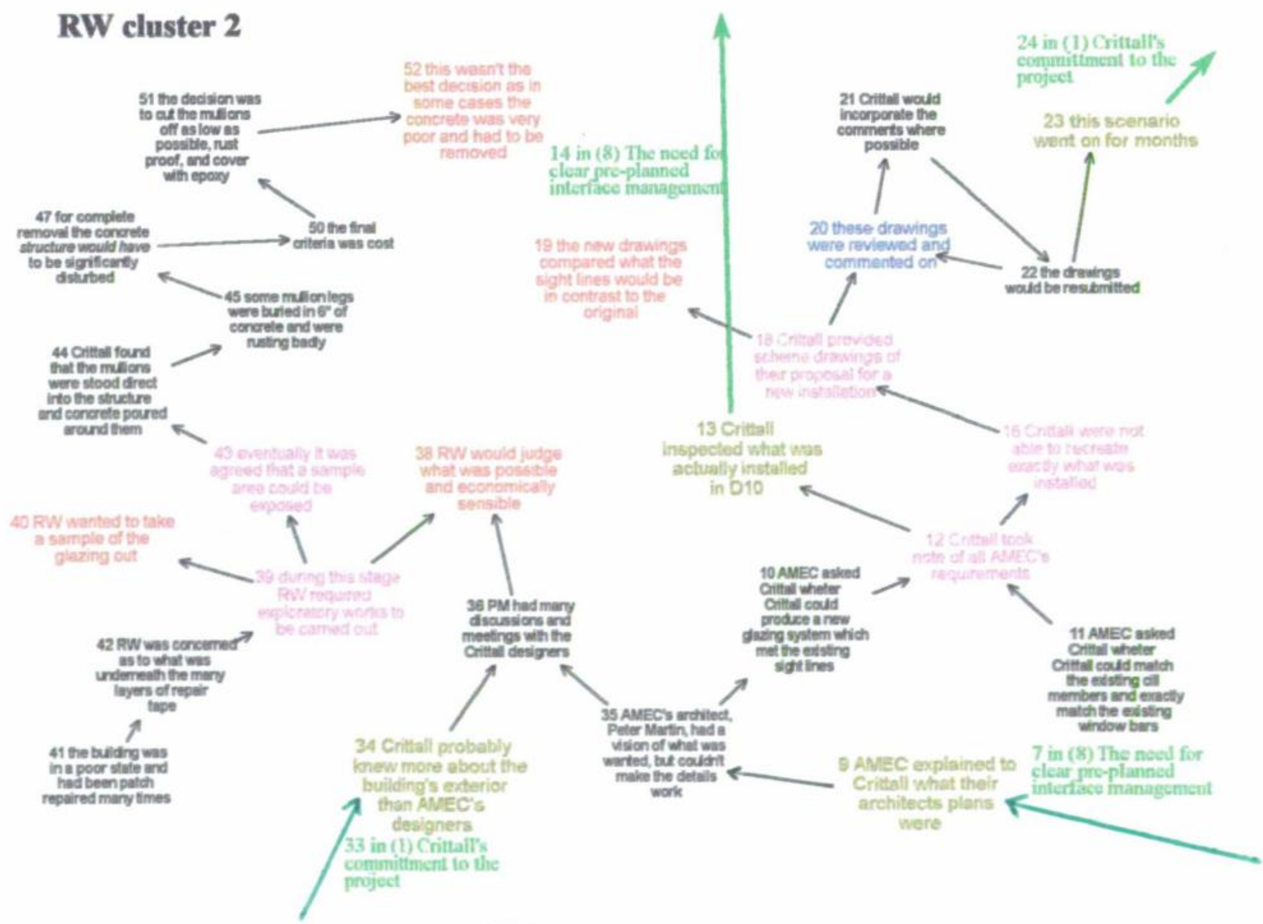
English Heritage 's perceived responsibilities



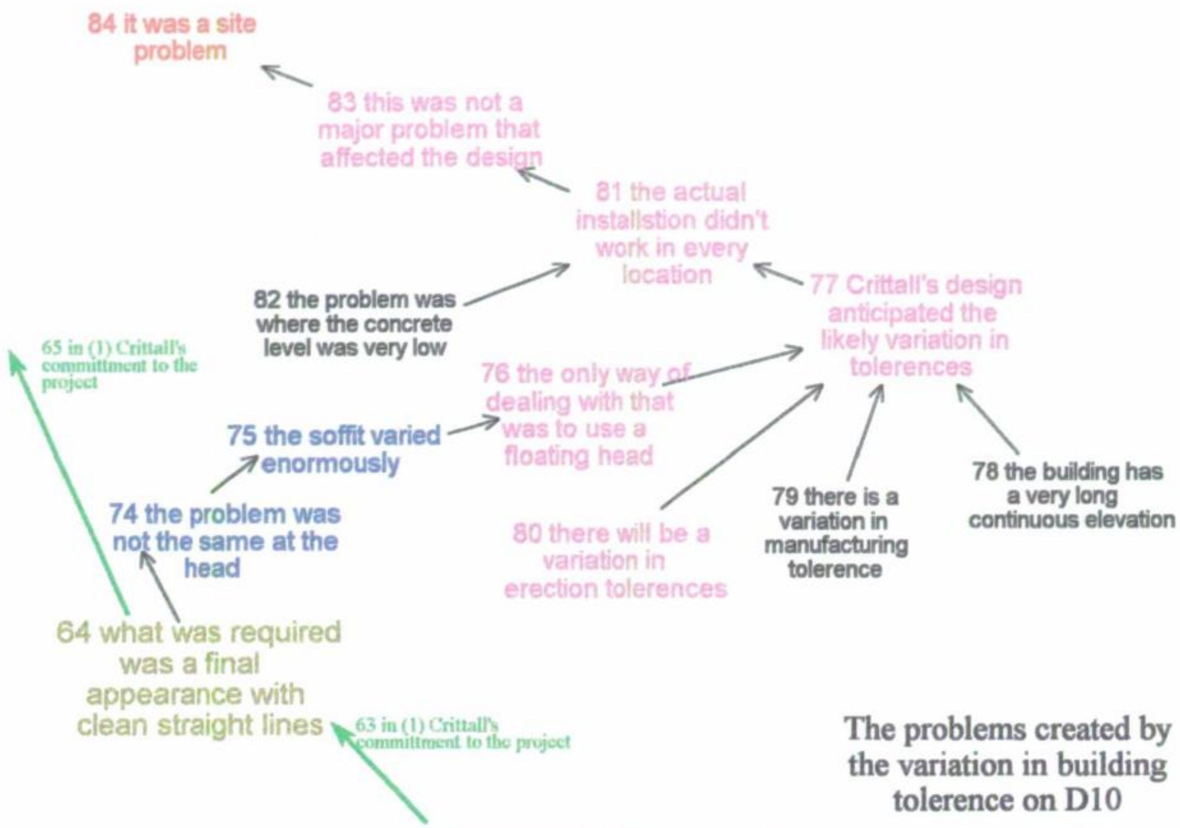
RW cluster 1



RW cluster 2

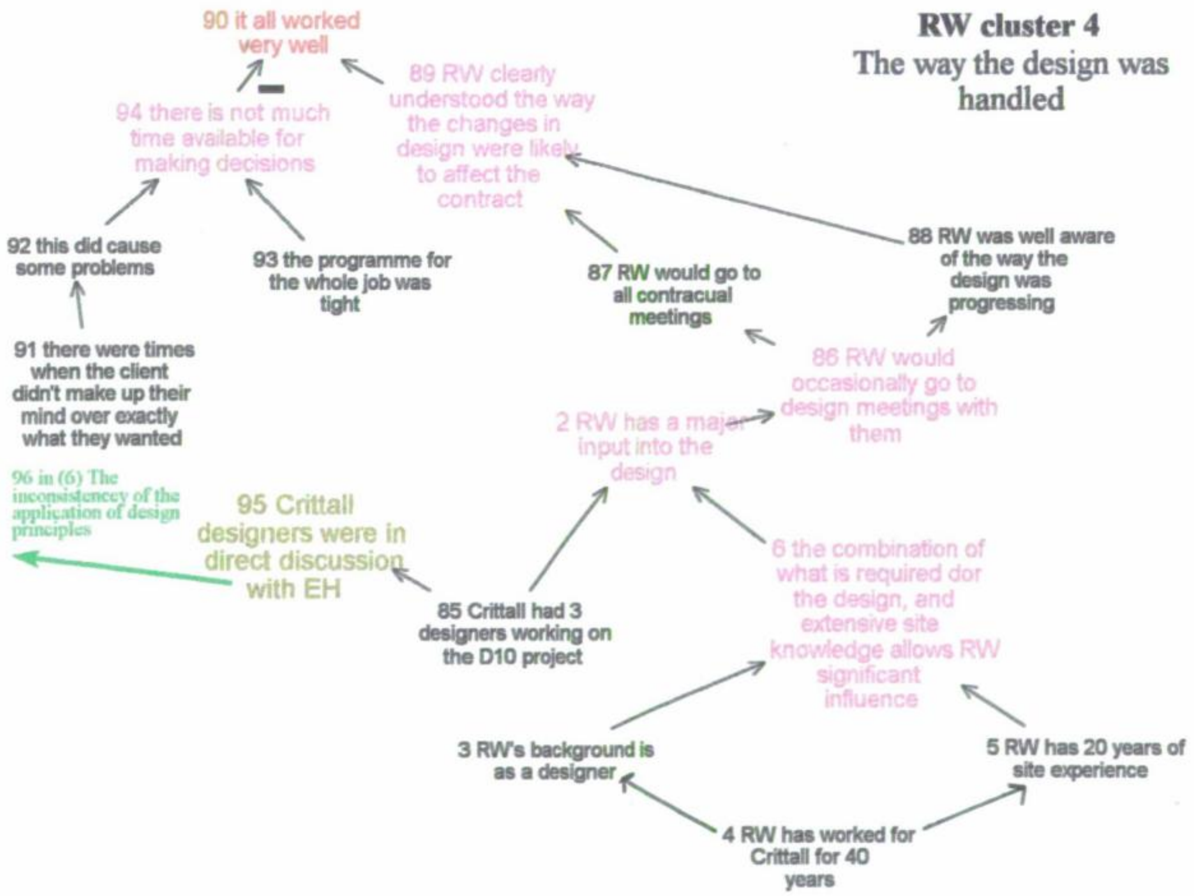


RW cluster 3

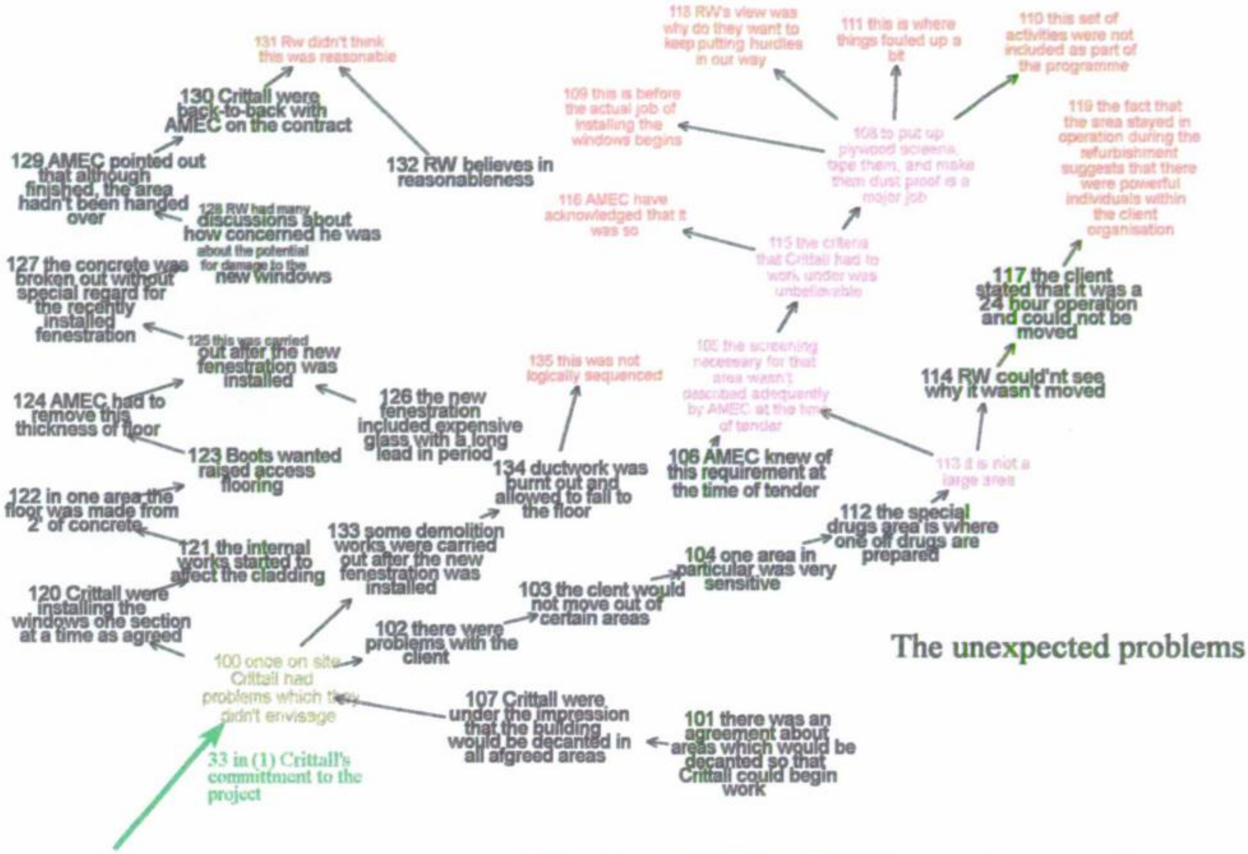


The problems created by the variation in building tolerence on D10

RW cluster 4
The way the design was handled



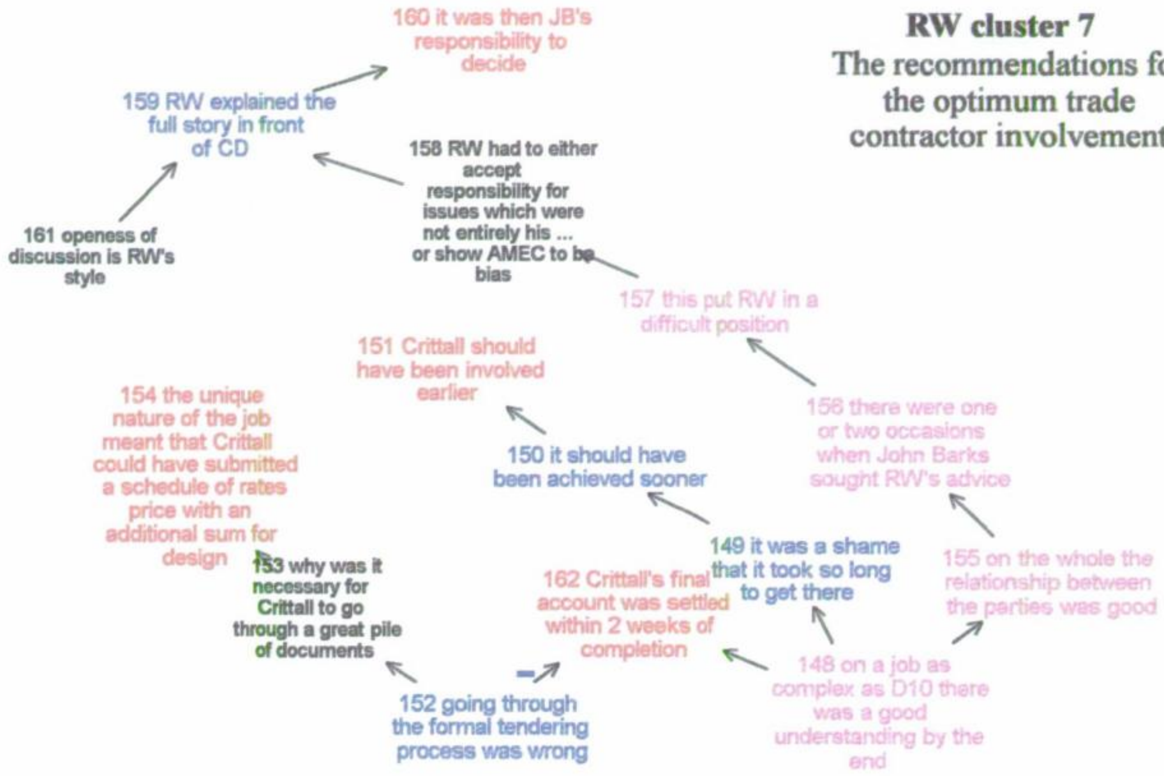
RW cluster 5



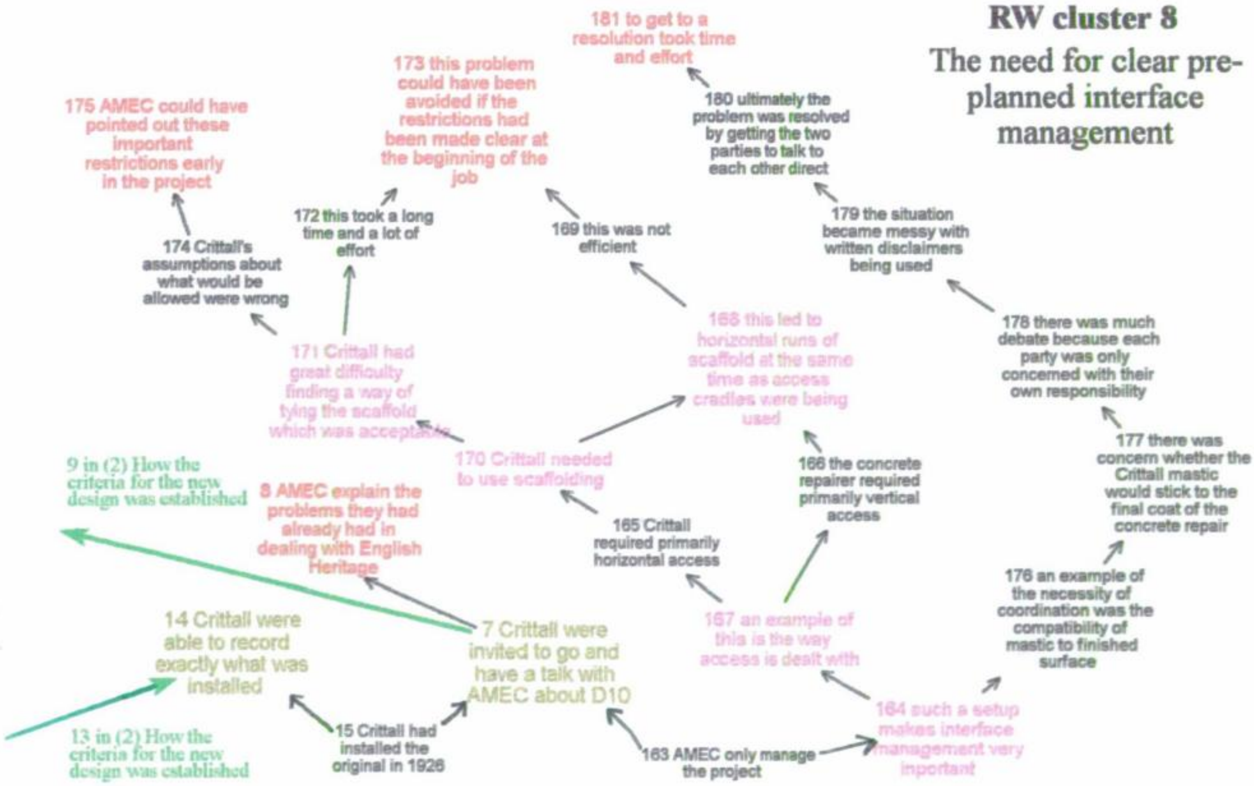
RW cluster 6

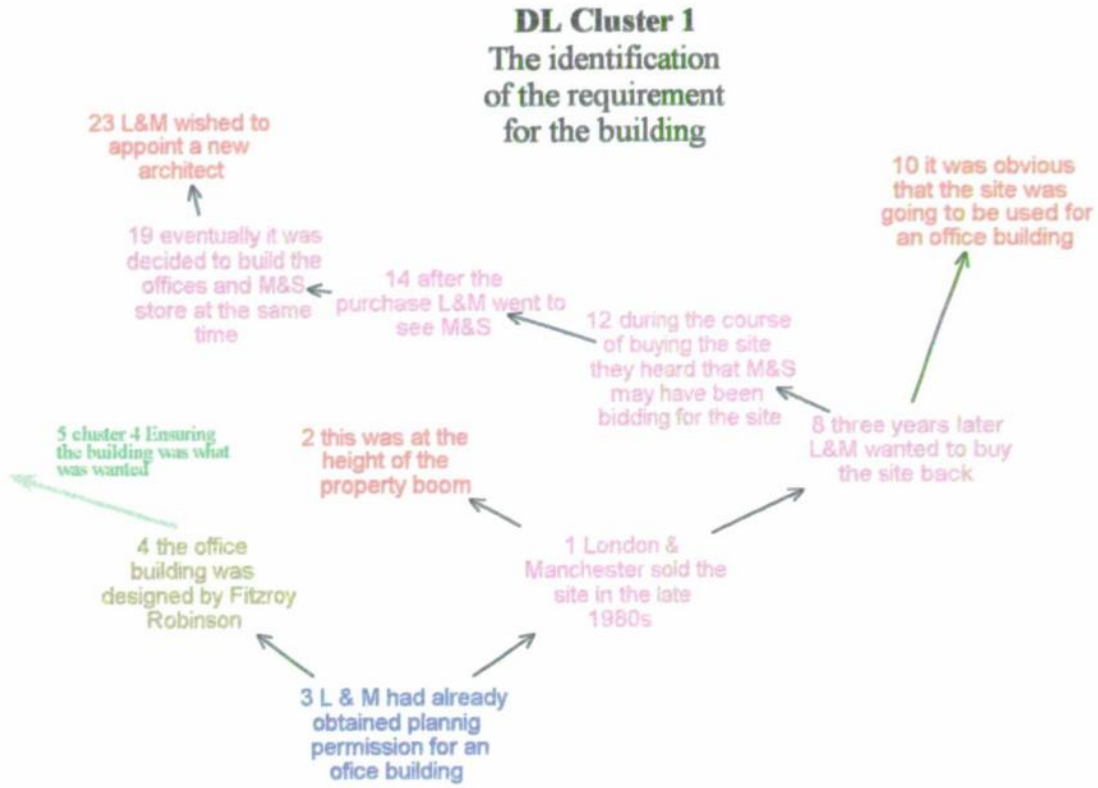
The inconsistencey of the application of design principles

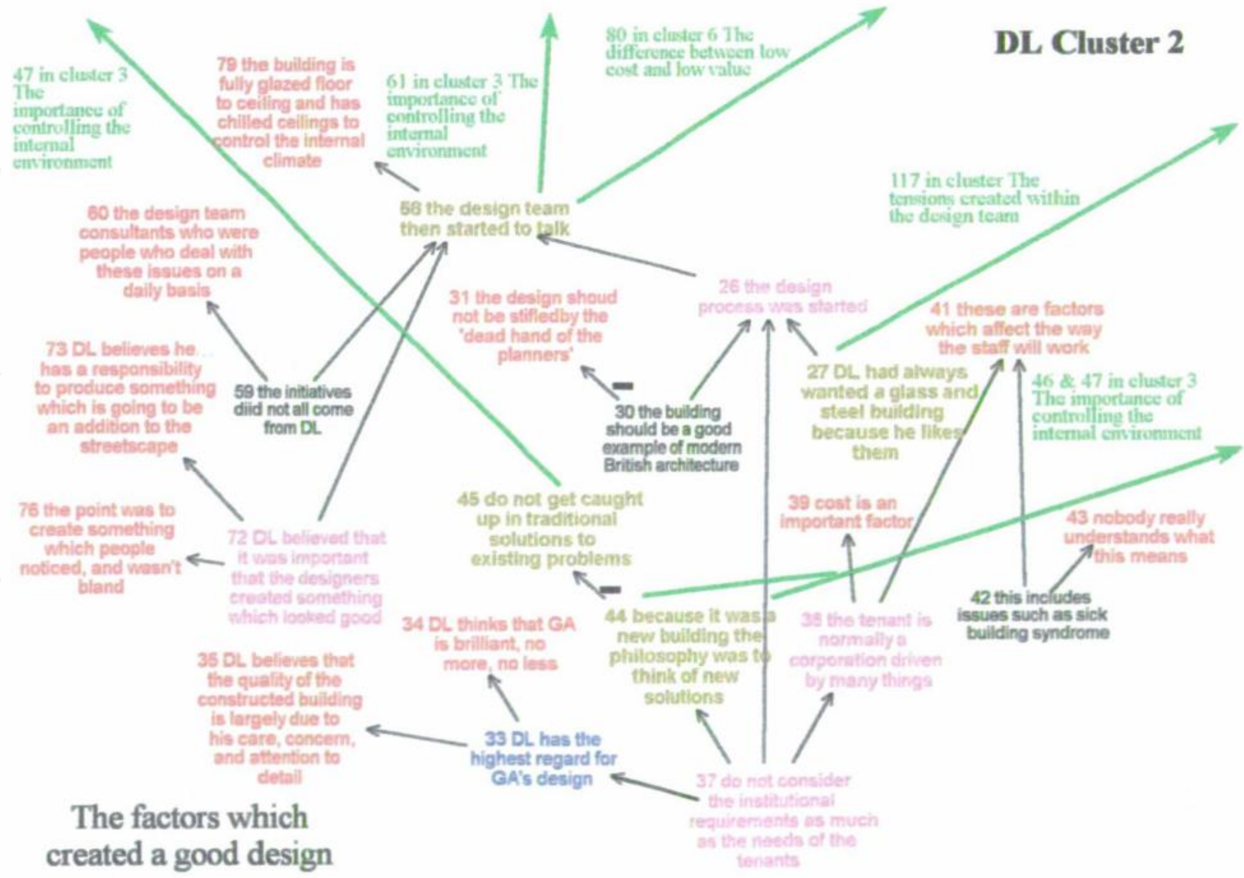
RW cluster 7
The recommendations for the optimum trade contractor involvement

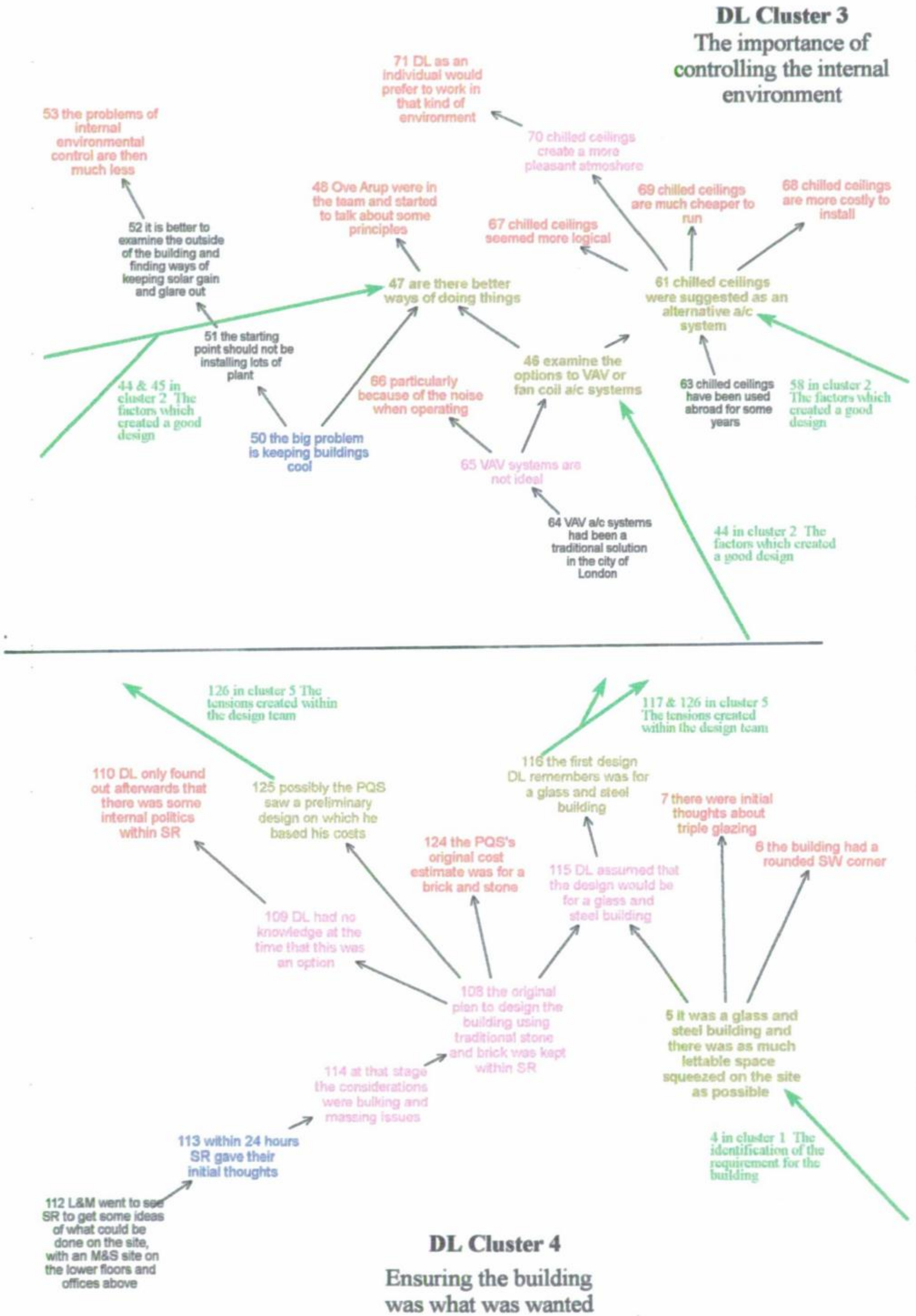


RW cluster 8
The need for clear pre-planned interface management

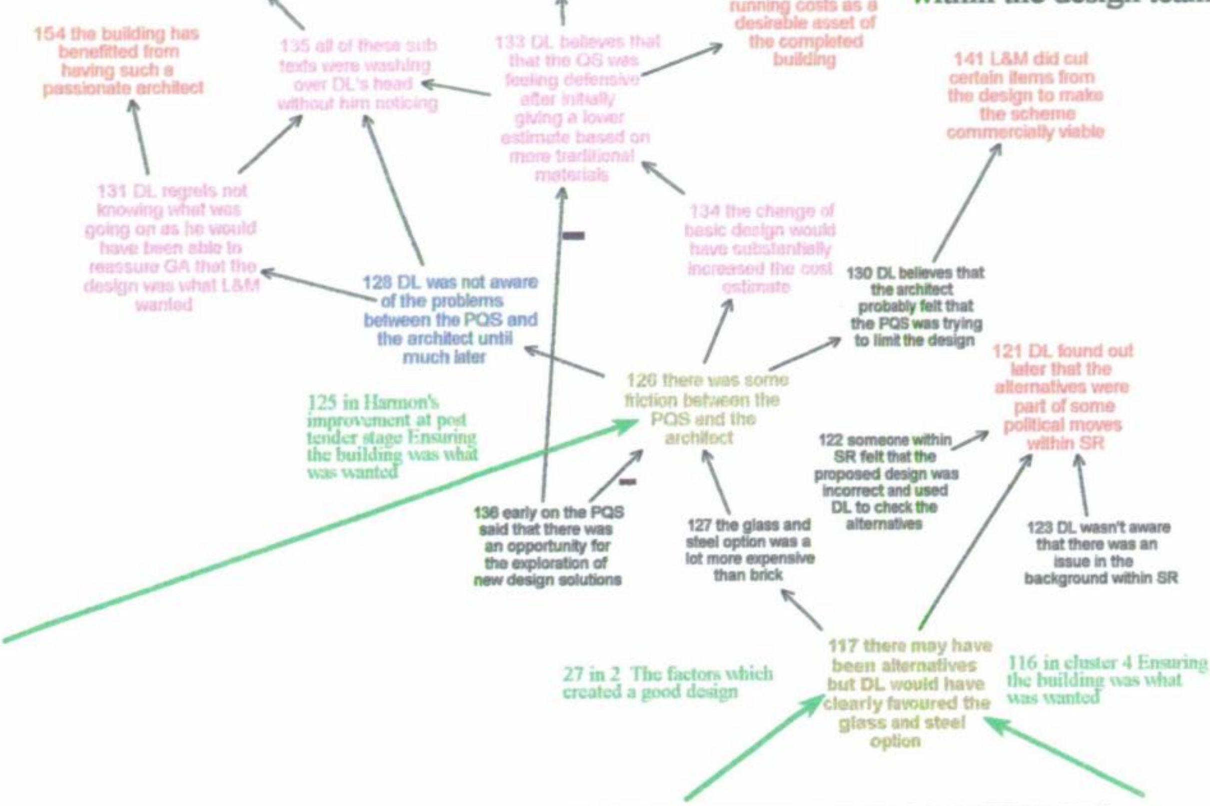



DL Cluster 1
The identification
of the requirement
for the building
23 L&M wished to appoint a new architect
19 eventually it was decided to build the offices and M&S store at the same time
14 after the purchase L&M went to see M&S
12 during the course of buying the site they heard that M&S may have been bidding for the site
10 it was obvious that the site was going to be used for an office building
8 three years later L&M wanted to buy the site back
5 cluster 4 Ensuring the building was what was wanted
2 this was at the height of the property boom
4 the office building was designed by Fitzroy Robinson
1 London & Manchester sold the site in the late 1980s
3 L & M had already obtained plannig permission for an office building

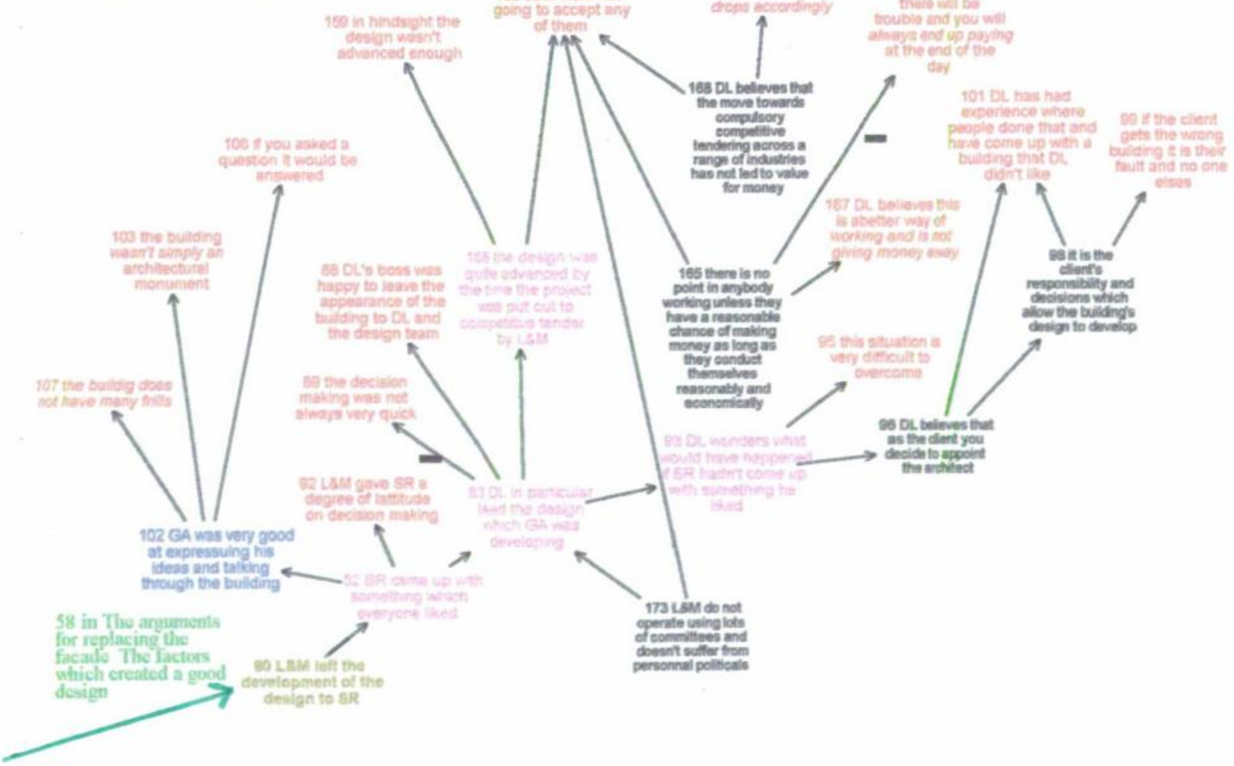

DL Cluster 2
47 in cluster 3 The importance of controlling the internal environment
79 the building is fully glazed floor to ceiling and has chilled ceilings to control the internal climate
61 in cluster 3 The importance of controlling the internal environment
80 in cluster 6 The difference between low cost and low value
117 in cluster The tensions created within the design team
58 the design team then started to talk
60 the design team consultants who were people who deal with these issues on a daily basis
26 the design process was started
31 the design shoud not be stifledby the 'dead hand of the planners'
41 these are factors which affect the way the staff will work
73 DL believes he has a responsibility to produce something which is going to be an addition to the streetscape
59 the initiatives diid not all come from DL
30 the building should be a good example of modern British architecture
27 DL had always wanted a glass and steel building because he likes them
46 & 47 in cluster 3 The importance of controlling the internal environment
76 the point was to create something which people noticed, and wasn't bland
72 DL believed that it was important that the designers created something which looked good
45 do not get caught up in traditional solutions to existing problems
39 cost is an important factor
43 nobody really understands what this means
34 DL thinks that GA is brilliant, no more, no less
44 because it was a new building the philosophy was to think of new solutions
38 the tenant is normally a corporation driven by many things
42 this includes issues such as sick building syndrome
35 DL believes that the quality of the constructed building is largely due to his care, concern, and attention to detail
33 DL has the highest regard for GA's design
37 do not consider the institutional requirements as much as the needs of the tenants
The factors which created a good design


DL Cluster 3
The importance of controlling the internal environment
71 DL as an individual would prefer to work in that kind of environment
70 chilled ceilings create a more pleasant atmoshere
53 the problems of internal environmental control are then much less
48 Ove Arup were in the team and started to talk about some principles
69 chilled ceilings are much cheaper to run
68 chilled ceilings are more costly to install
67 chilled ceilings seemed more logical
52 it is better to examine the outside of the building and finding ways of keeping solar gain and glare out
47 are there better ways of doing things
61 chilled ceilings were suggested as an alternative a/c system
51 the starting point should not be installing lots of plant
46 examine the options to VAV or fan coil a/c systems
44 & 45 in cluster 2 The factors which created a good design
66 particularly because of the noise when operating
63 chilled ceilings have been used abroad for some years
58 in cluster 2 The factors which created a good design
50 the big problem is keeping buildings cool
65 VAV systems are not ideal
64 VAV a/c systems had been a traditional solution in the city of London
44 in cluster 2 The factors which created a good design
126 in cluster 5 The tensions created within the design team
117 & 126 in cluster 5 The tensions created within the design team
116 the first design DL remembers was for a glass and steel building
110 DL only found out afterwards that there was some internal politics within SR
125 possibly the PQS saw a preliminary design on which he based his costs
7 there were initial thoughts about triple glazing
124 the PQS's original cost estimate was for a brick and stone
115 DL assumed that the design would be for a glass and steel building
6 the building had a rounded SW corner
109 DL had no knowledge at the time that this was an option
108 the original plan to design the building using traditional stone and brick was kept within SR
5 it was a glass and steel building and there was as much lettable space squeezed on the site as possible
114 at that stage the considerations were bulking and massing issues
113 within 24 hours SR gave their initial thoughts
4 in cluster 1 The identification of the requirement for the building
112 L&M went to see SR to get some ideas of what could be done on the site, with an M&S site on the lower floors and offices above
DL Cluster 4
Ensuring the building was what was wanted

DL Cluster 5
The tensions created within the design team



DL Cluster 6
The difference between low cost and low value

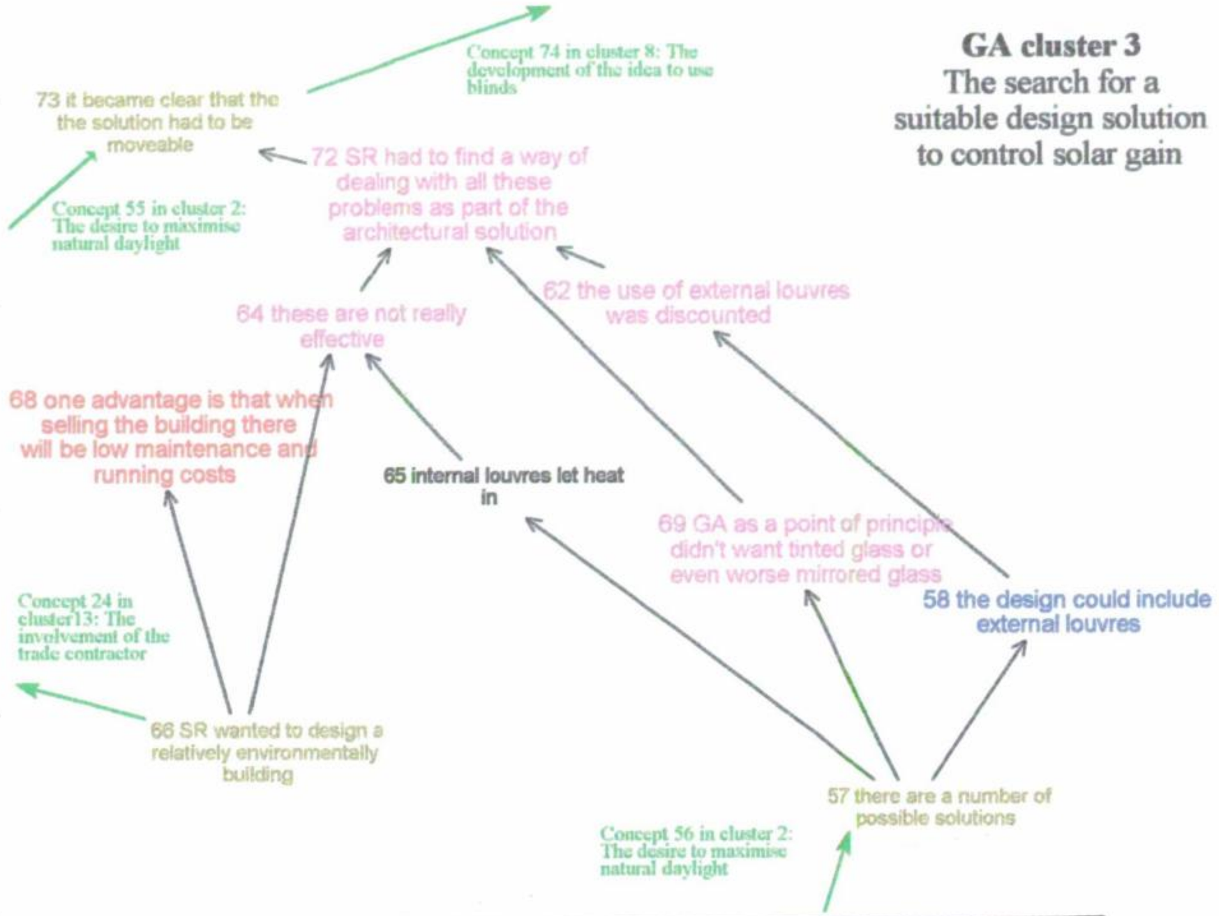


DL Cluster 7
The justification for using personal judgement in making key decisions

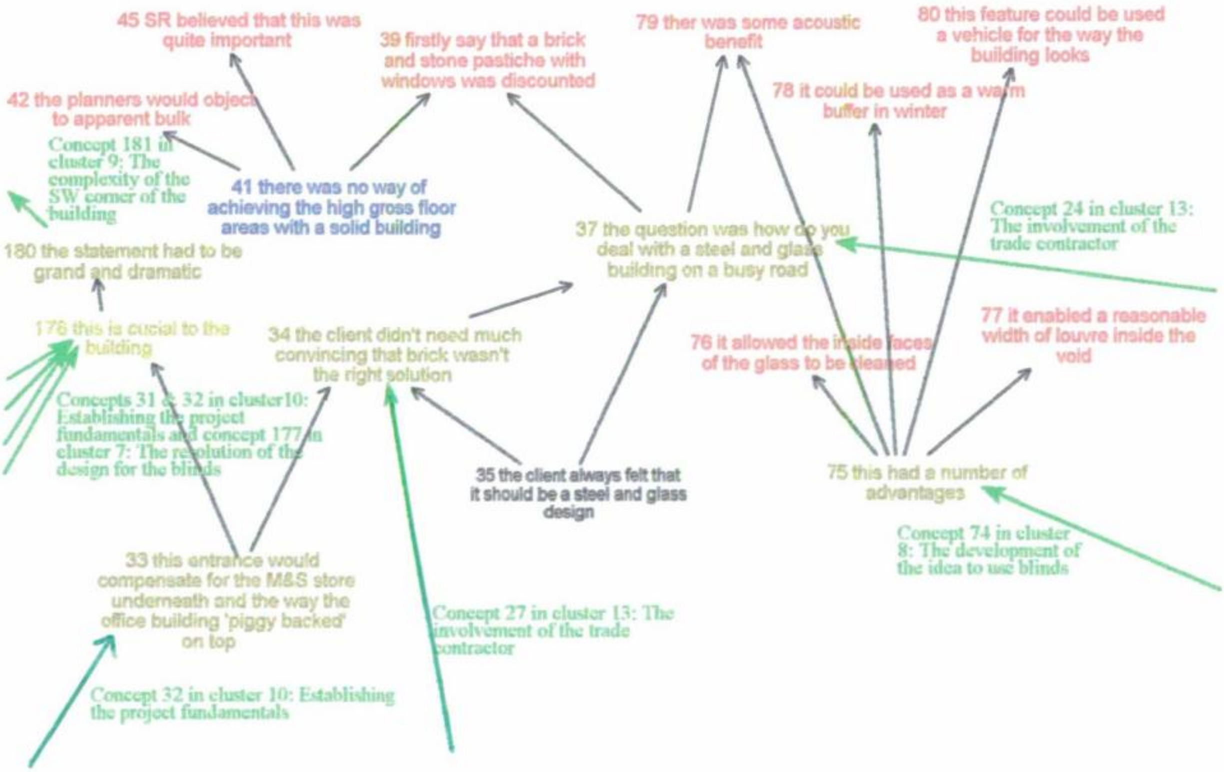
GA cluster 1
The drivers for the project

GA cluster 2
The desire to maximise natural daylight

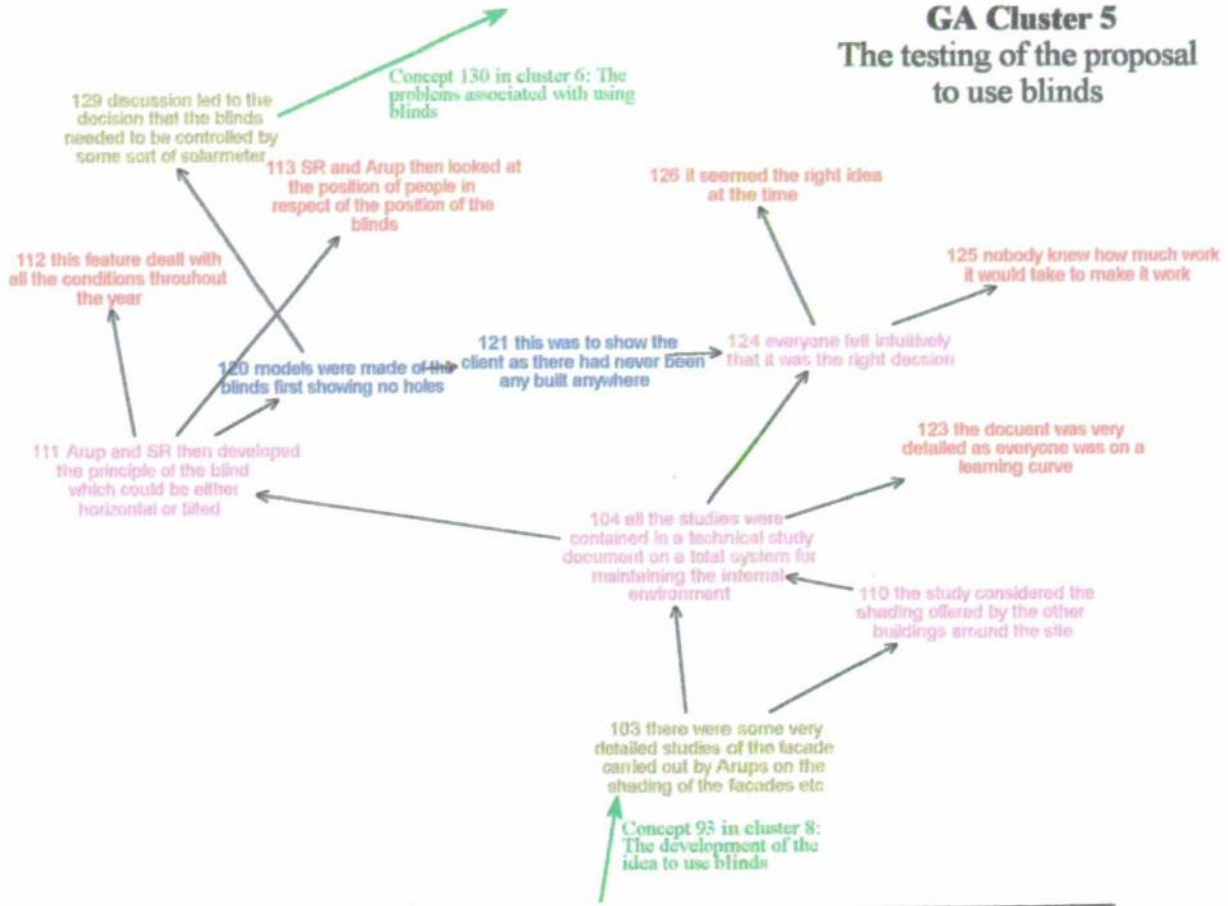
GA cluster 3
The search for a suitable design solution to control solar gain



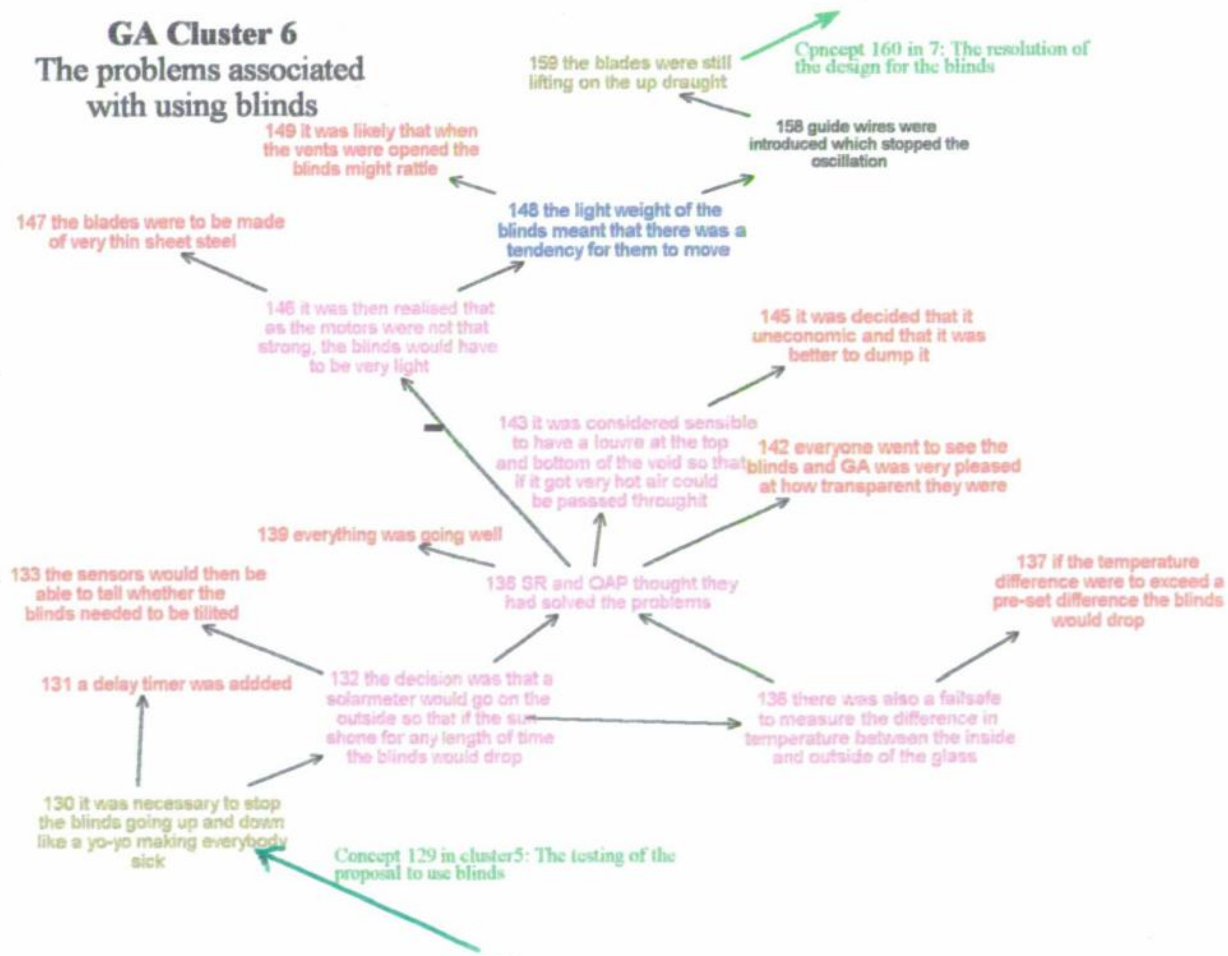
GA cluster 4
The fundamental options for the building



GA Cluster 5
The testing of the proposal to use blinds

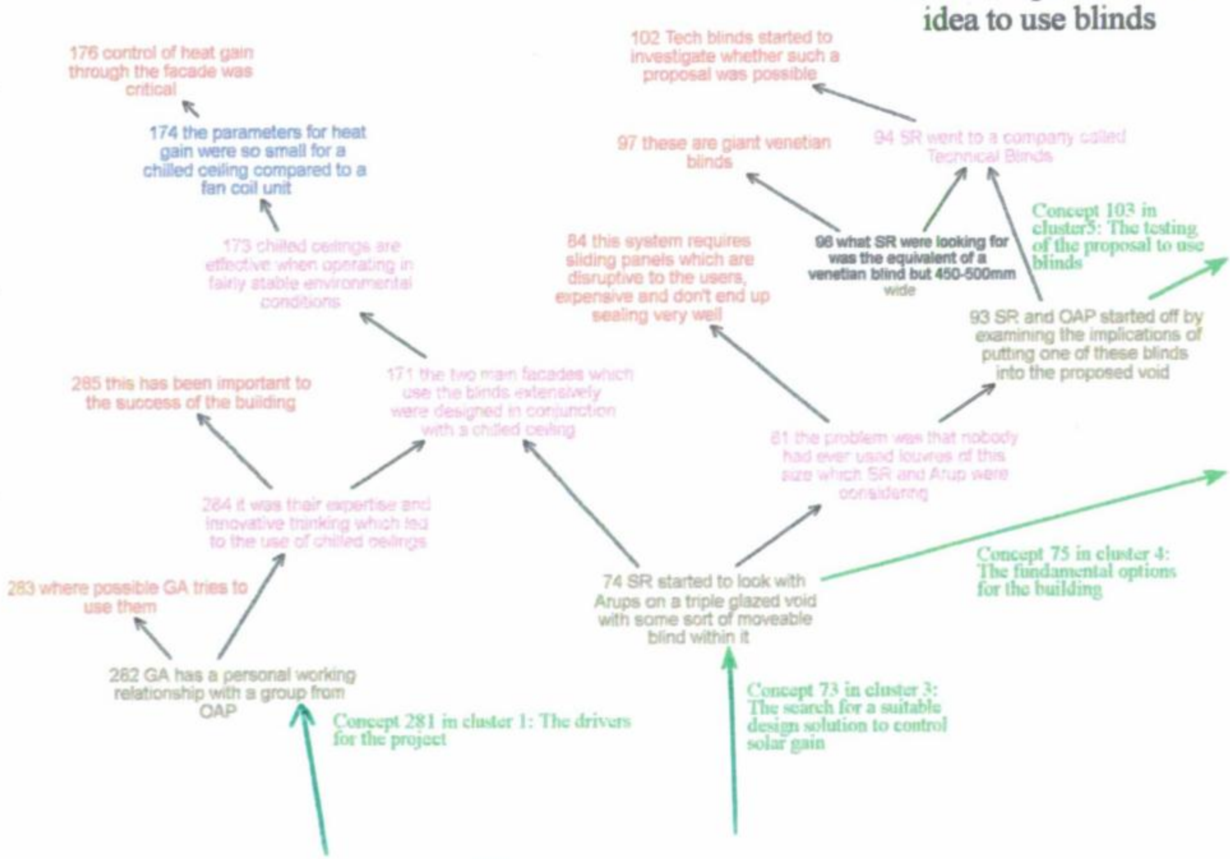


GA Cluster 6
The problems associated with using blinds

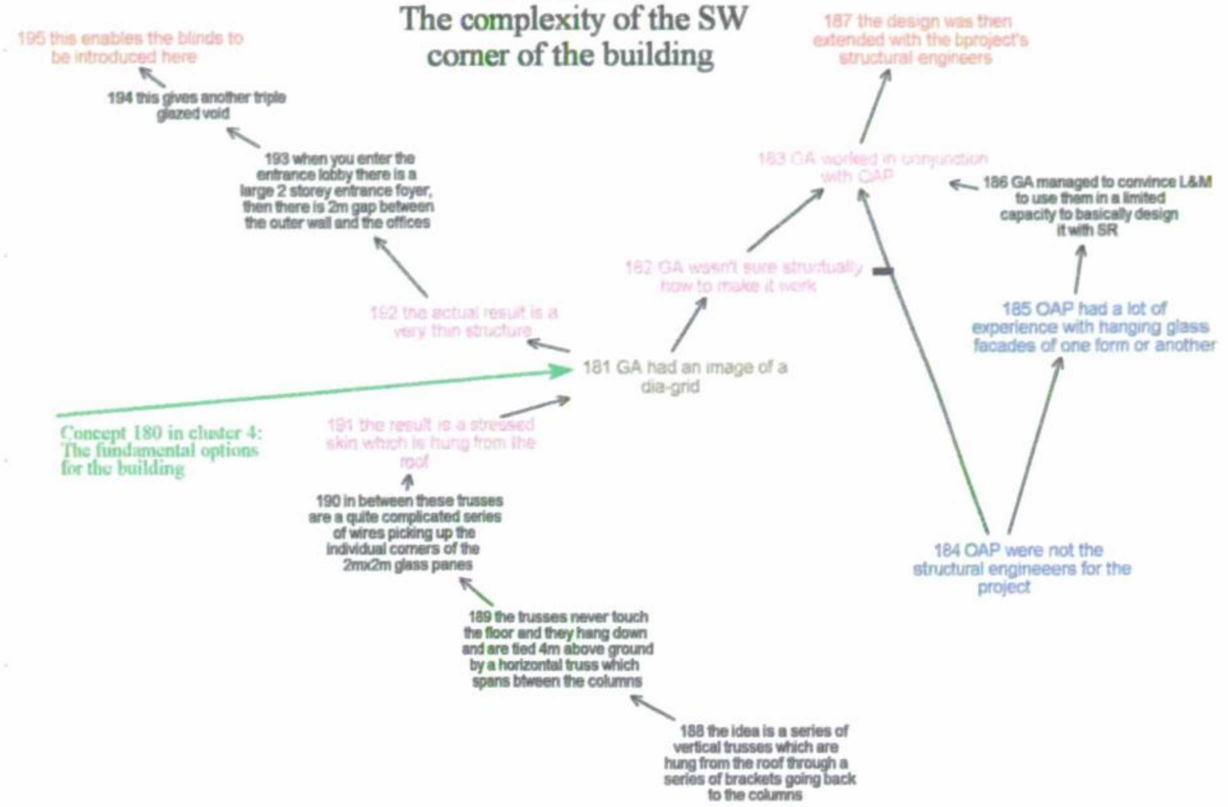


GA Cluster 7
The resolution of the design for the blinds

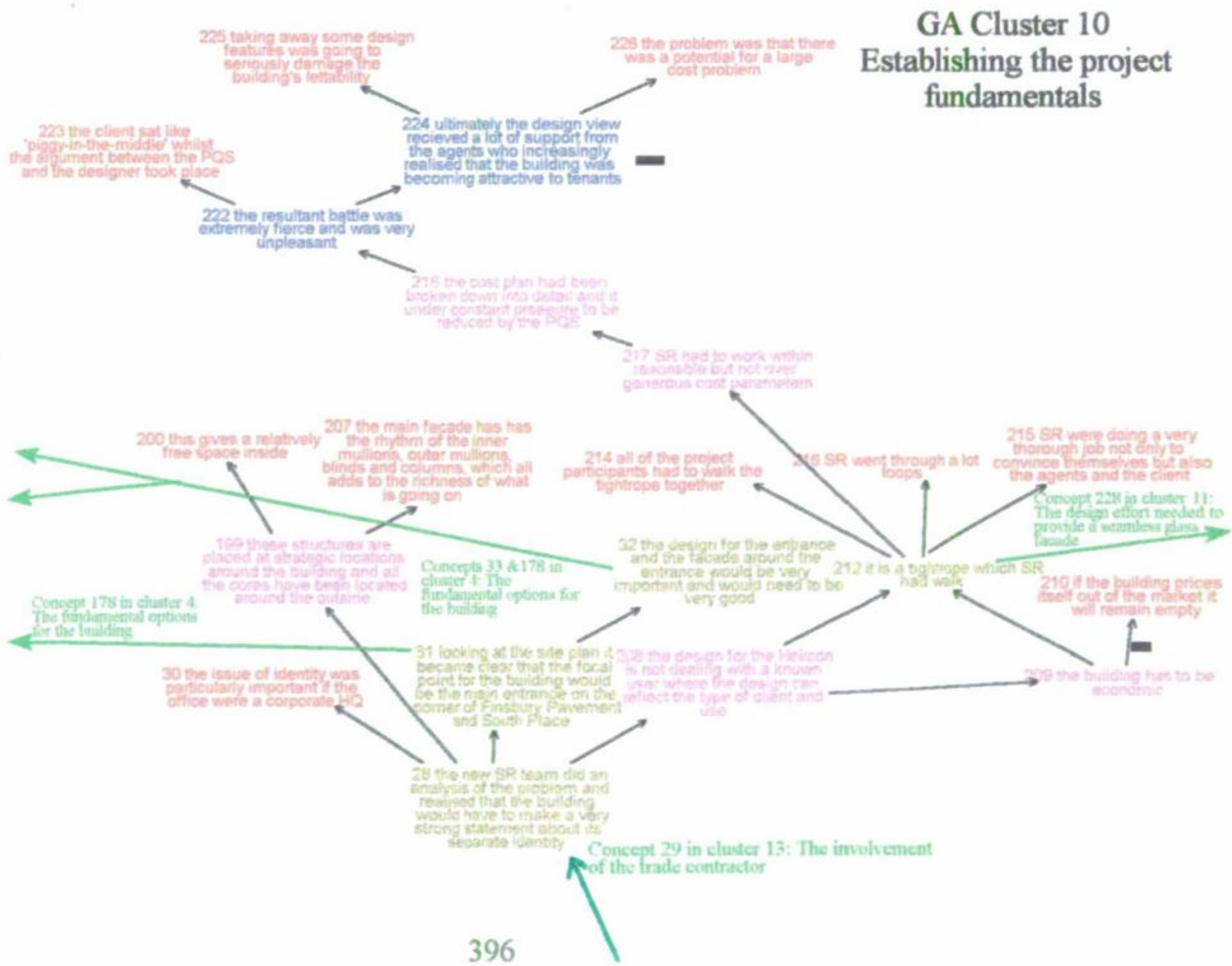
GA Cluster 8
The development of the idea to use blinds



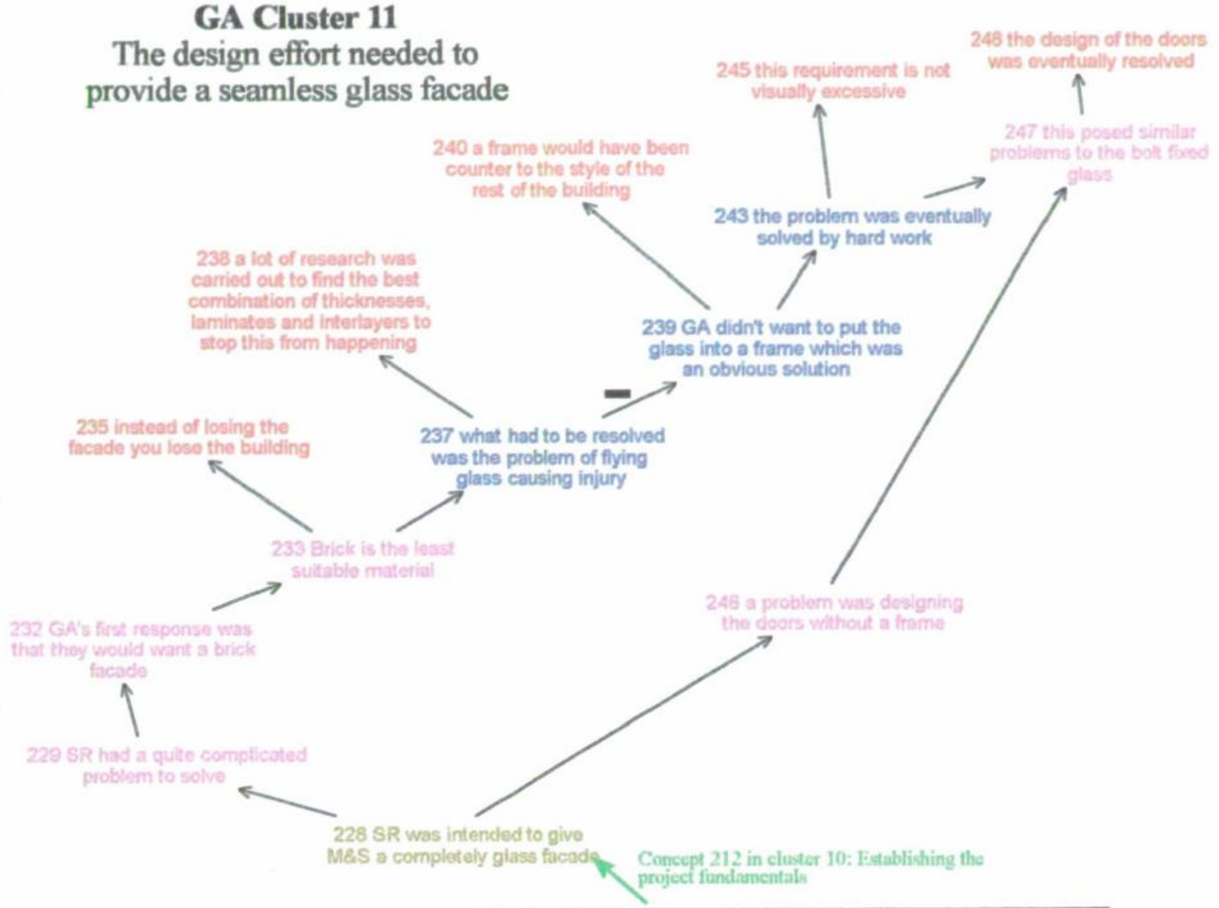
GA Cluster 9
The complexity of the SW corner of the building



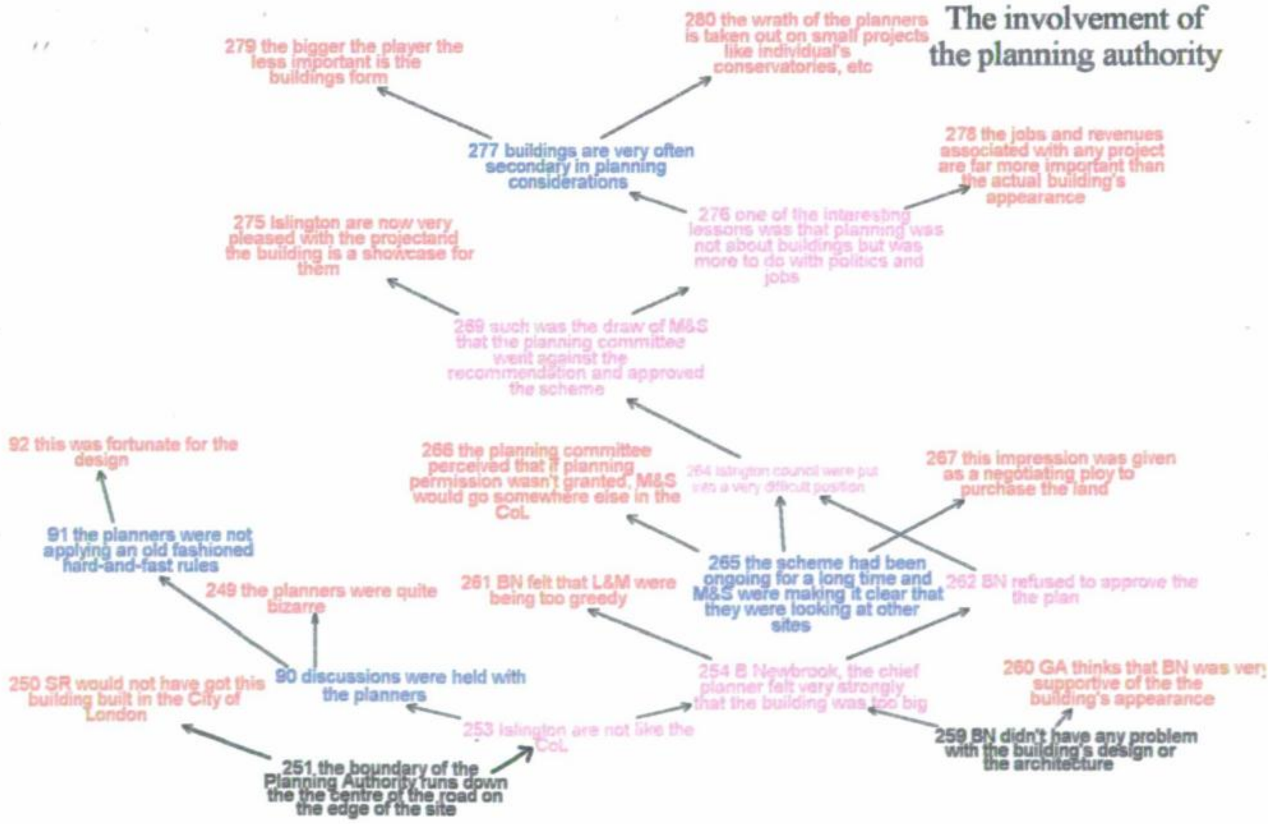
GA Cluster 10
Establishing the project fundamentals



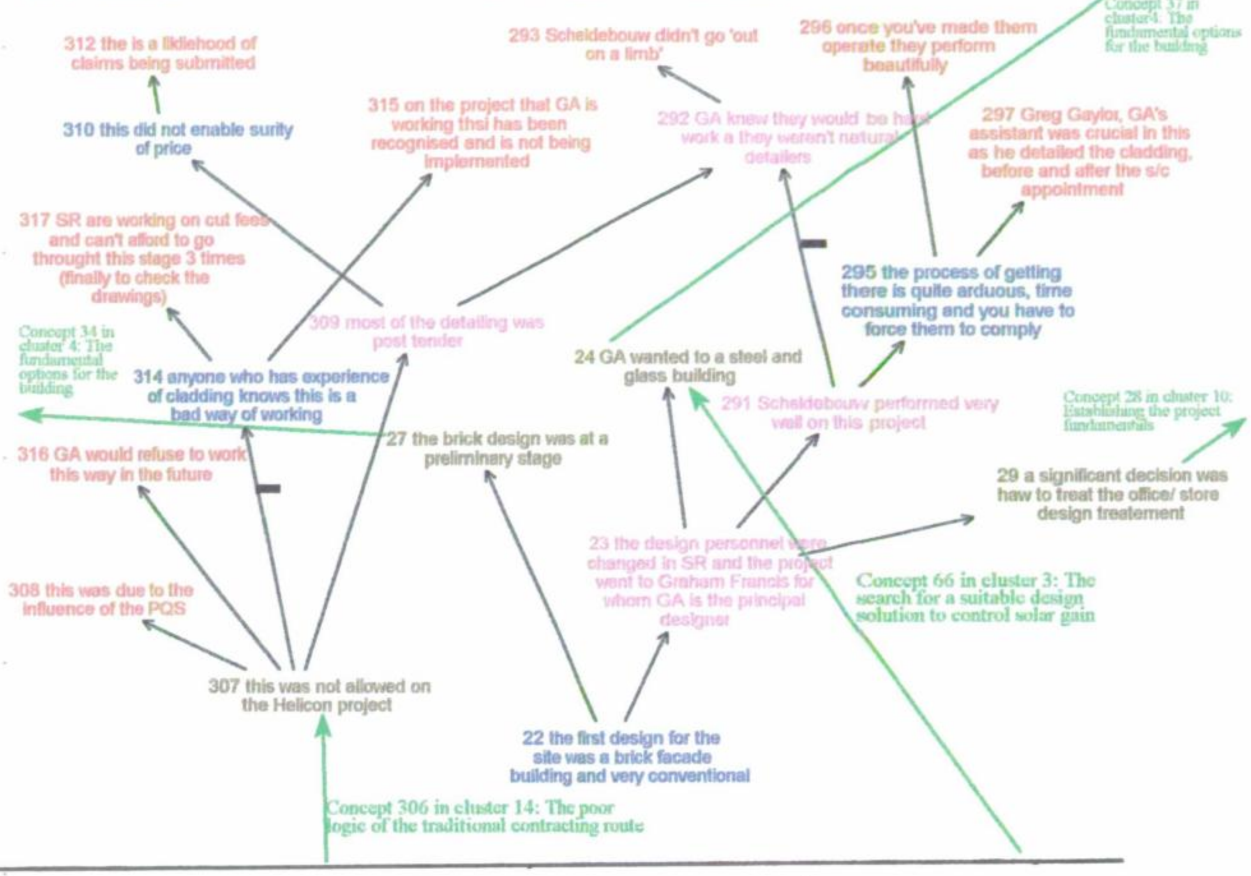
GA Cluster 11
The design effort needed to provide a seamless glass facade



GA Cluster 12
The involvement of the planning authority

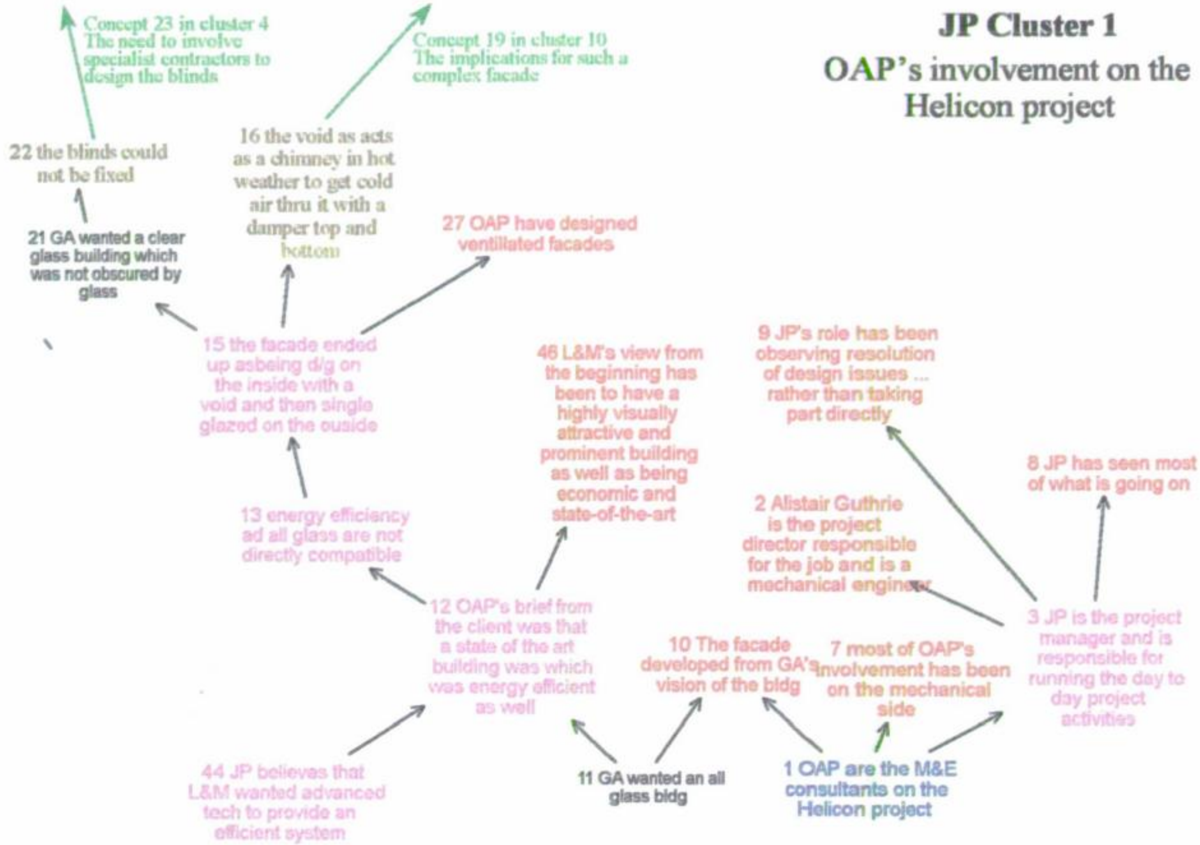


GA Cluster 13 The involvement of the trade contractor

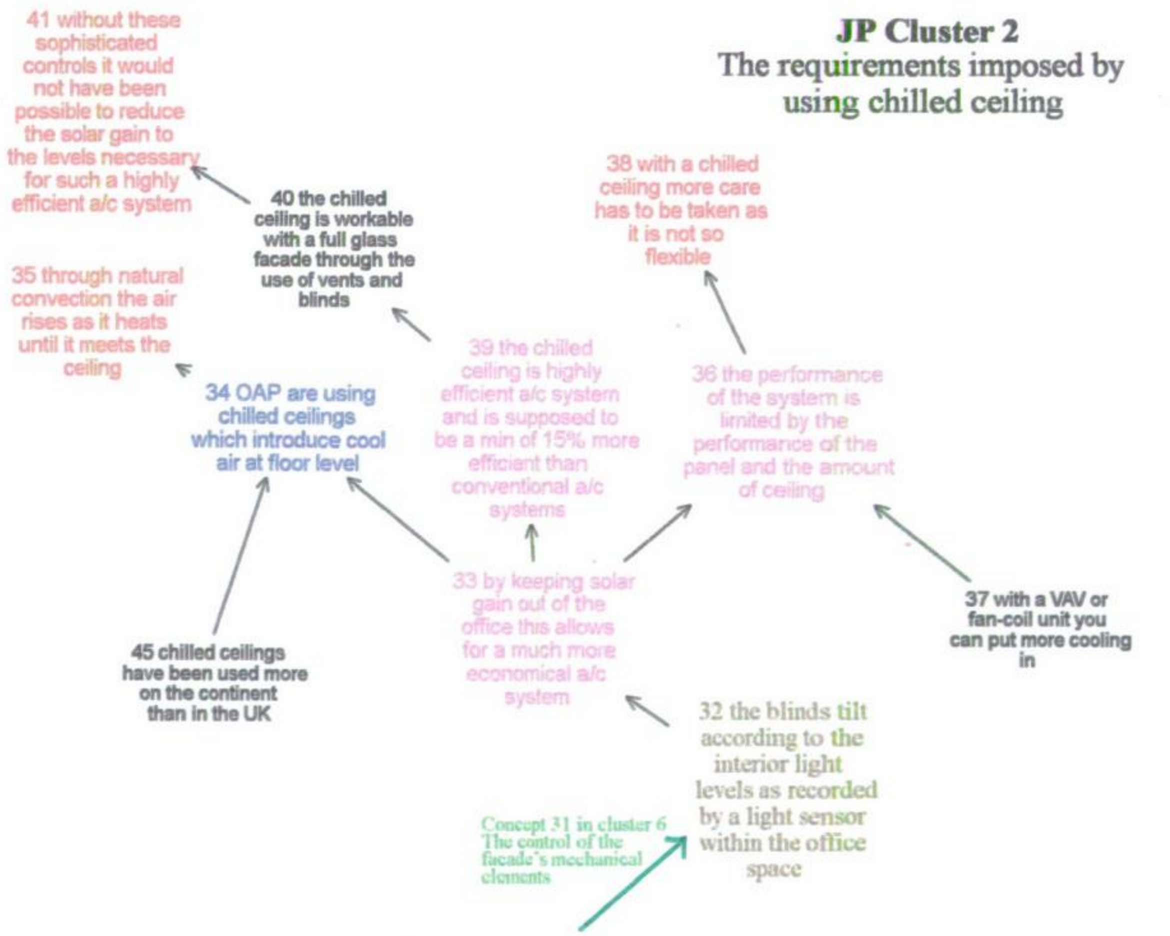


GA cluster 14
The poor logic of the traditional contracting route

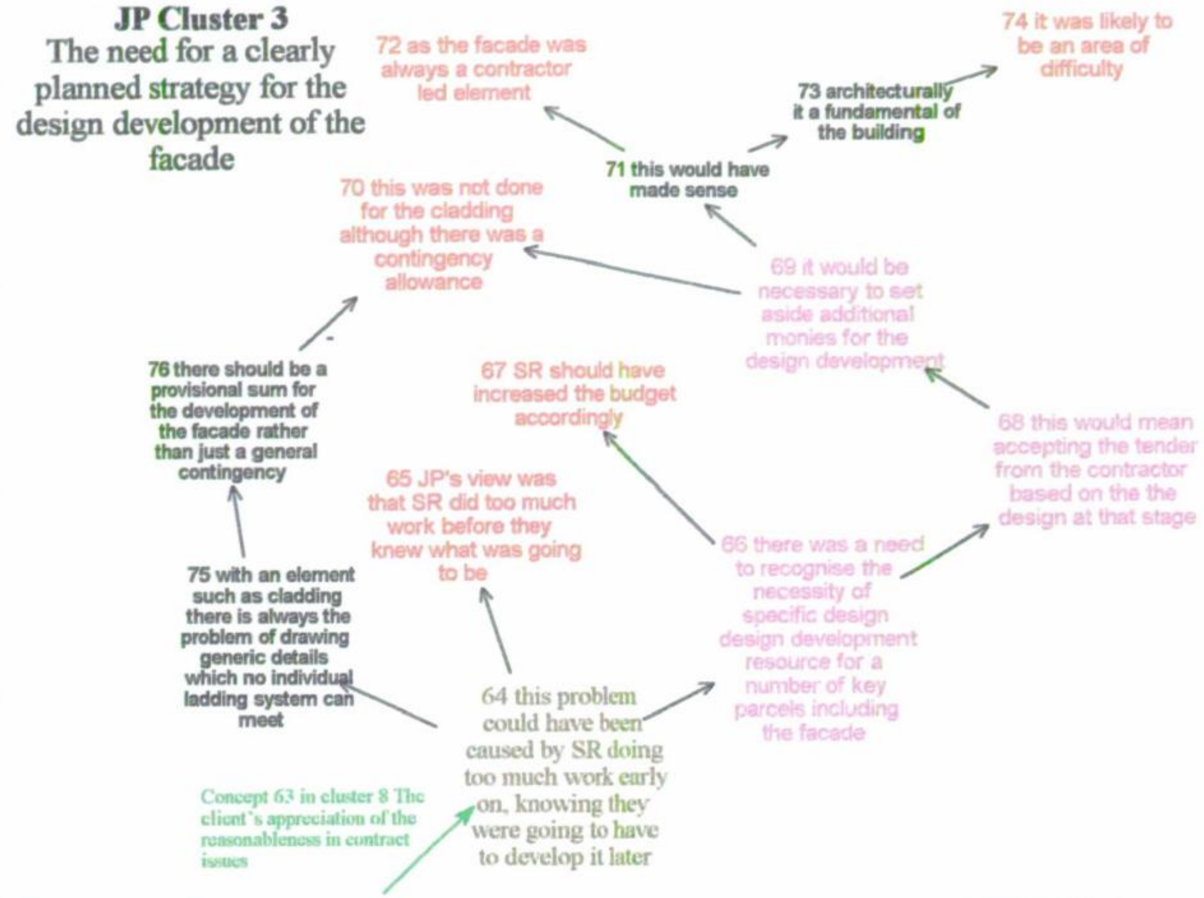
JP Cluster 1
OAP's involvement on the Helicon project



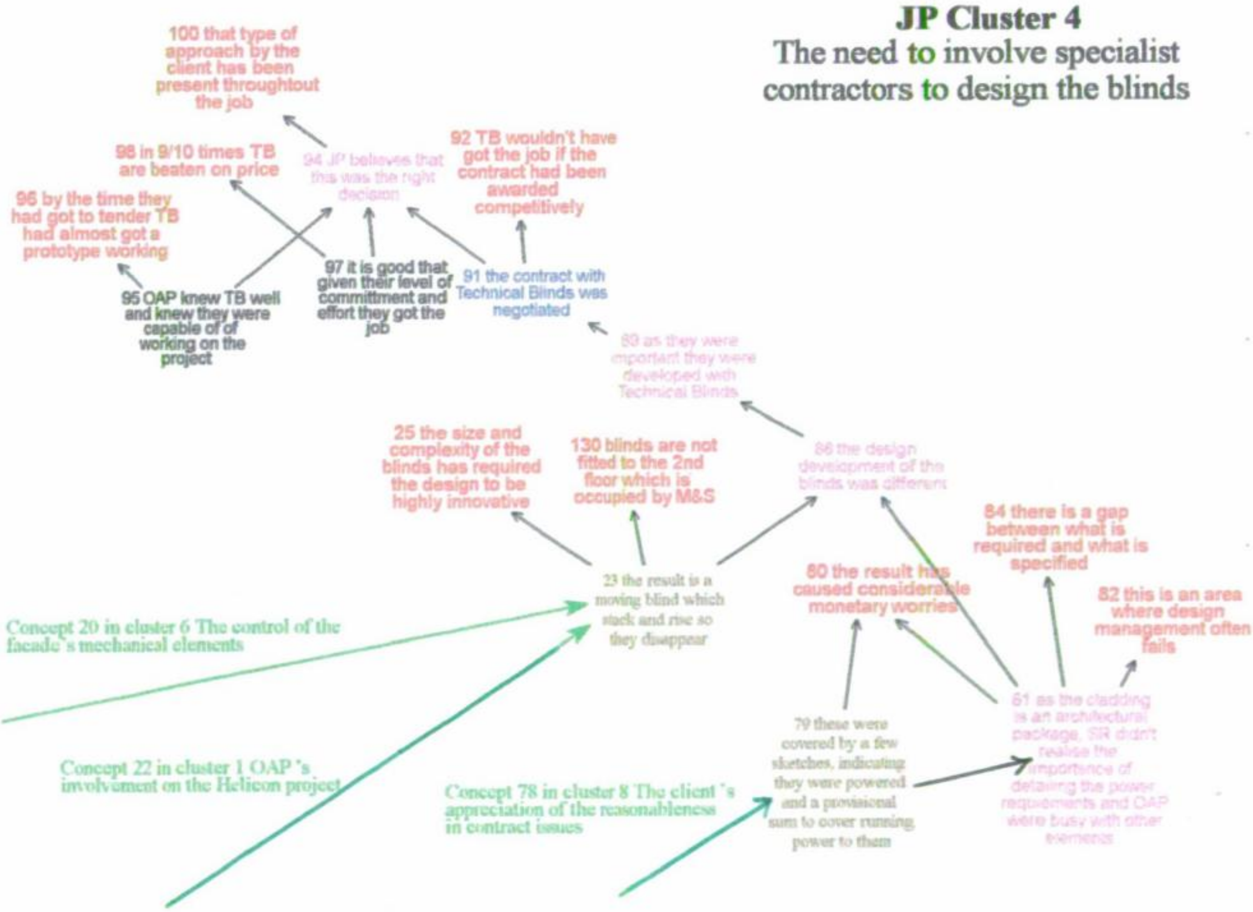
JP Cluster 2
The requirements imposed by using chilled ceiling



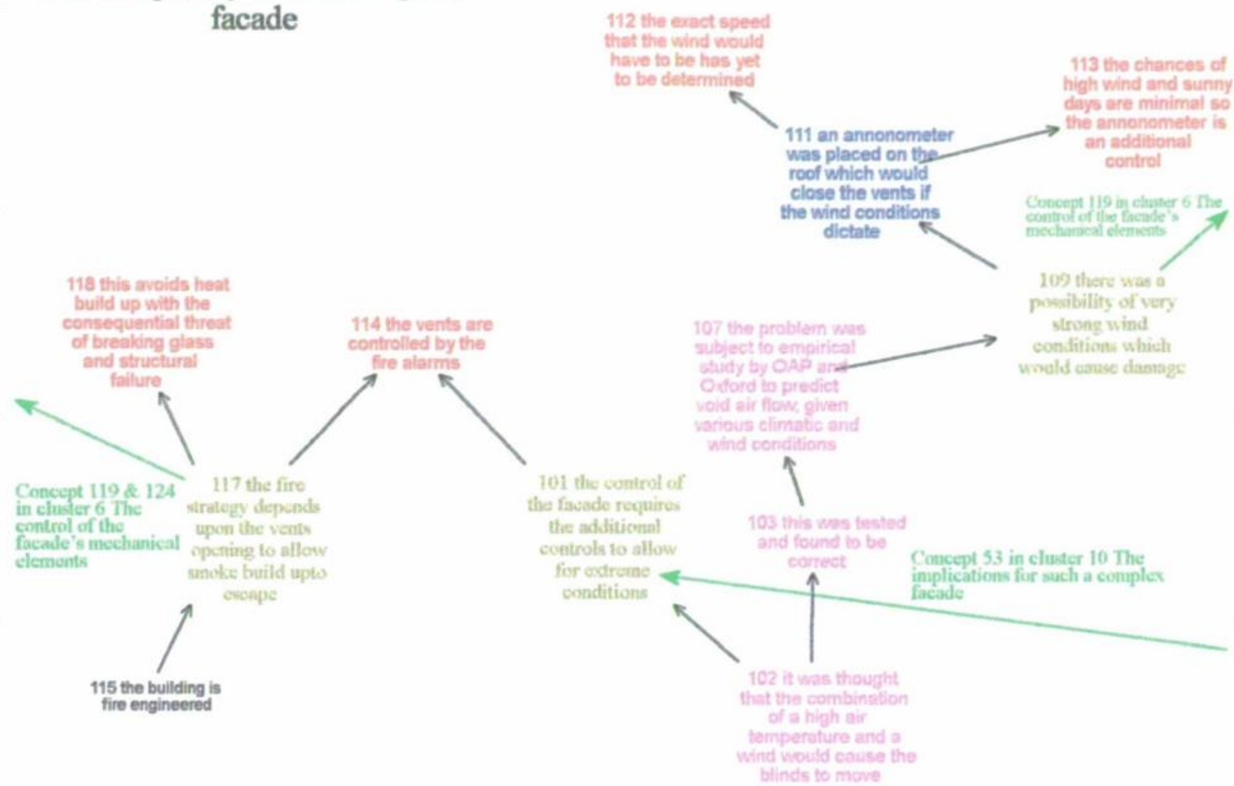
JP Cluster 3
The need for a clearly planned strategy for the design development of the facade



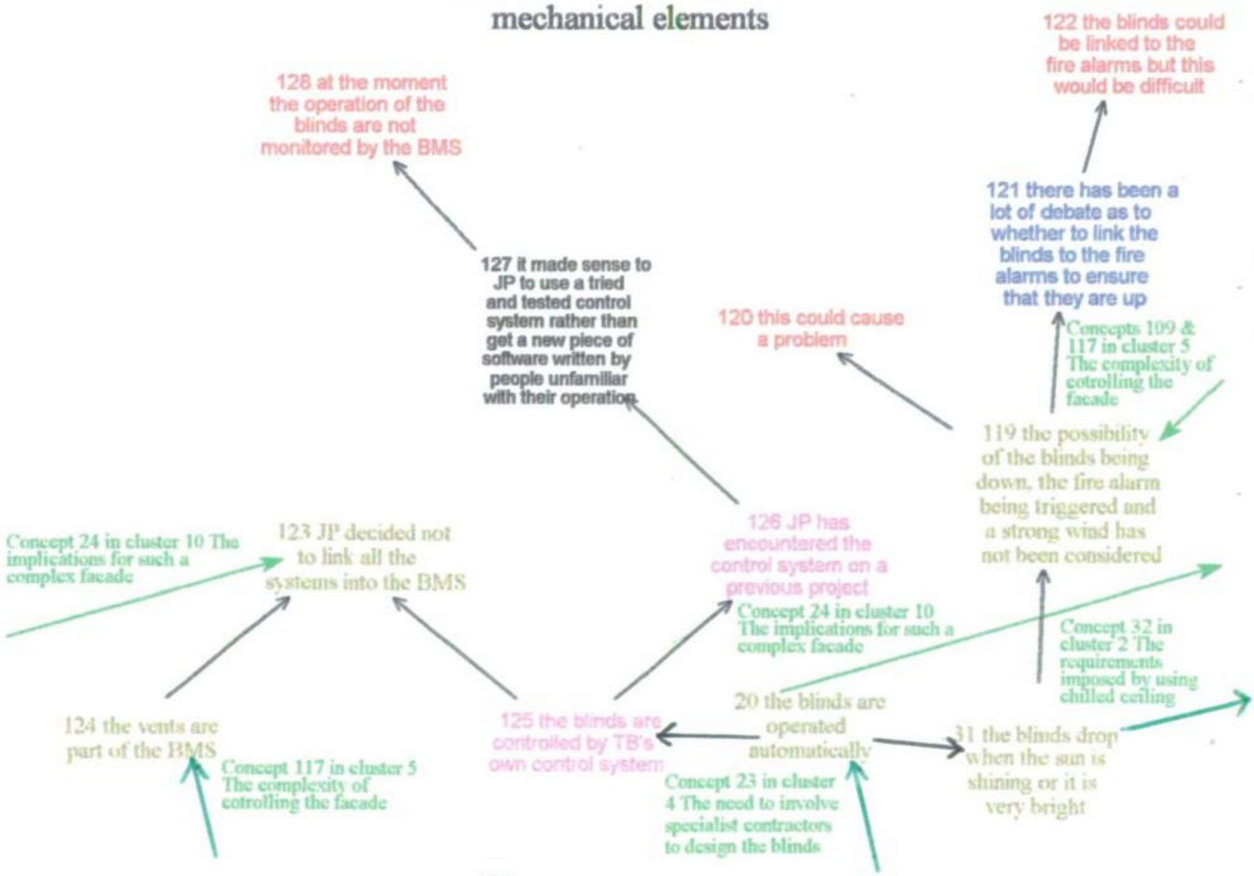
JP Cluster 4
The need to involve specialist contractors to design the blinds



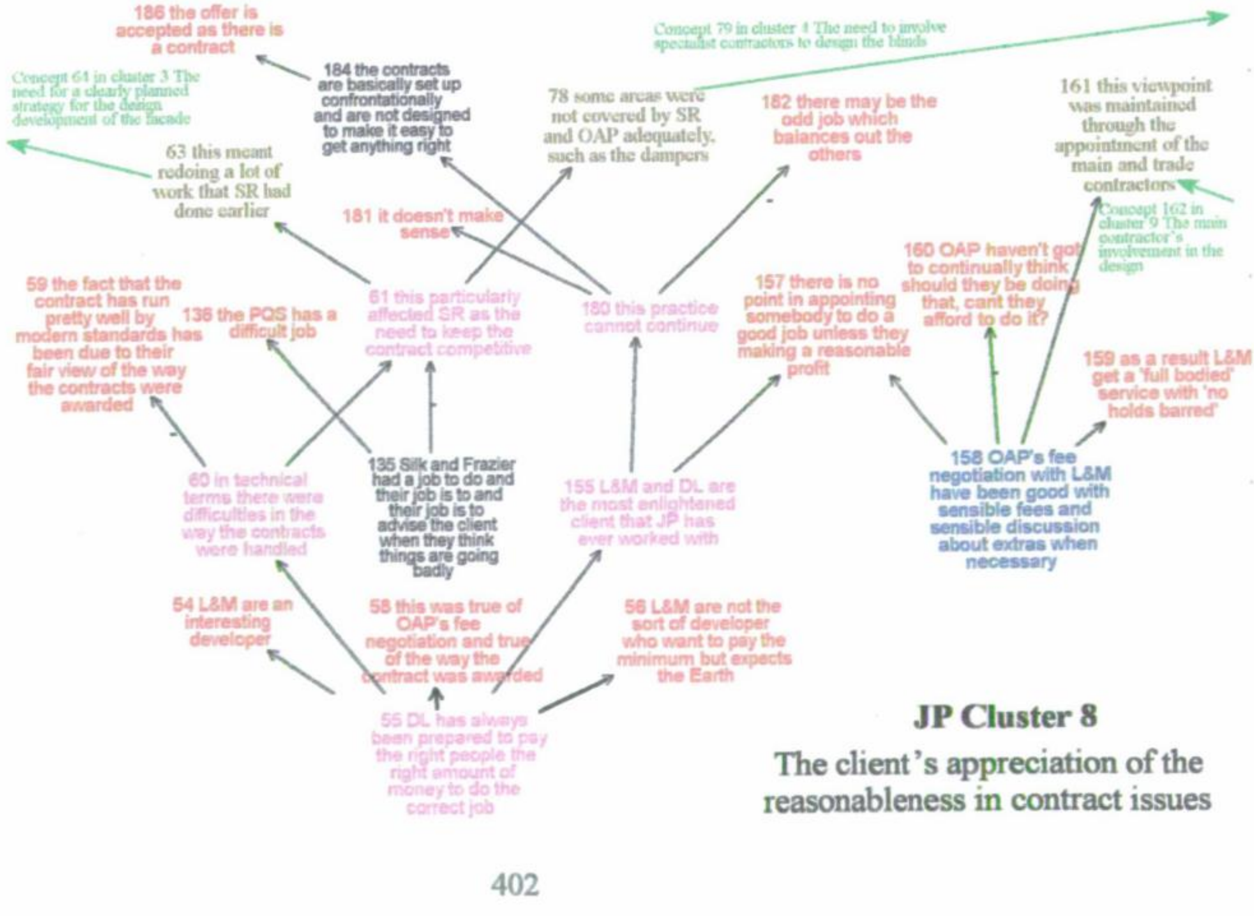
JP Cluster 5
The complexity of cotrolling the facade



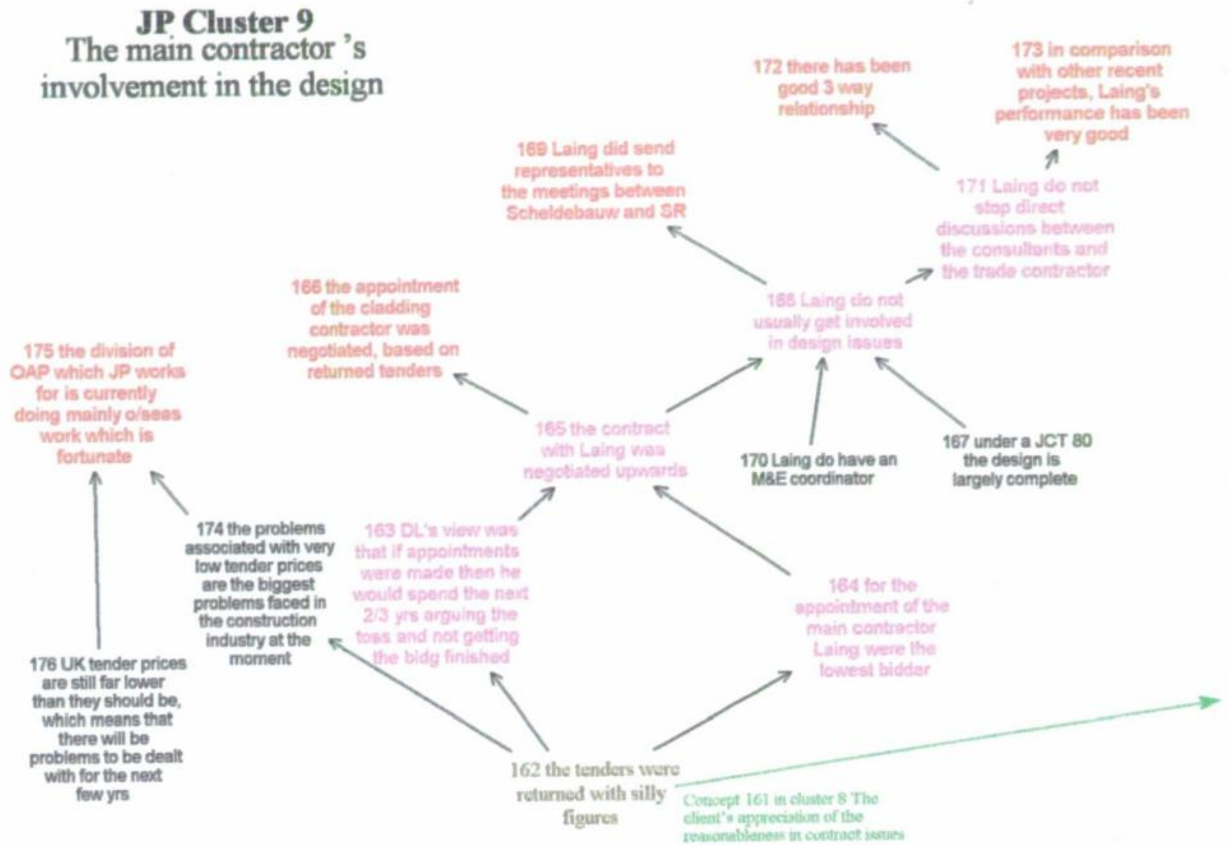
JP Cluster 6
The control of the facade 's mechanical elements

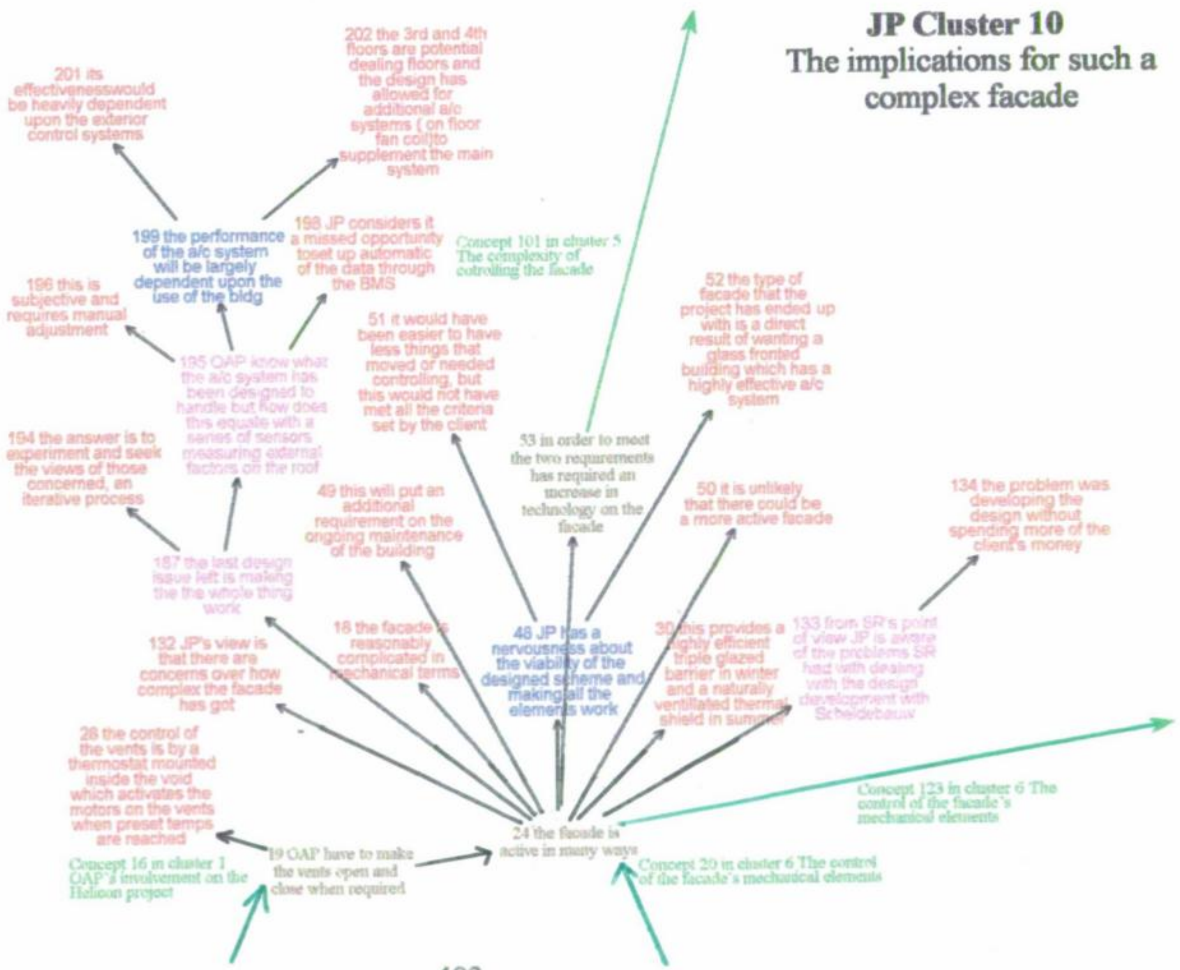


JP Cluster 7
The different types of PQS

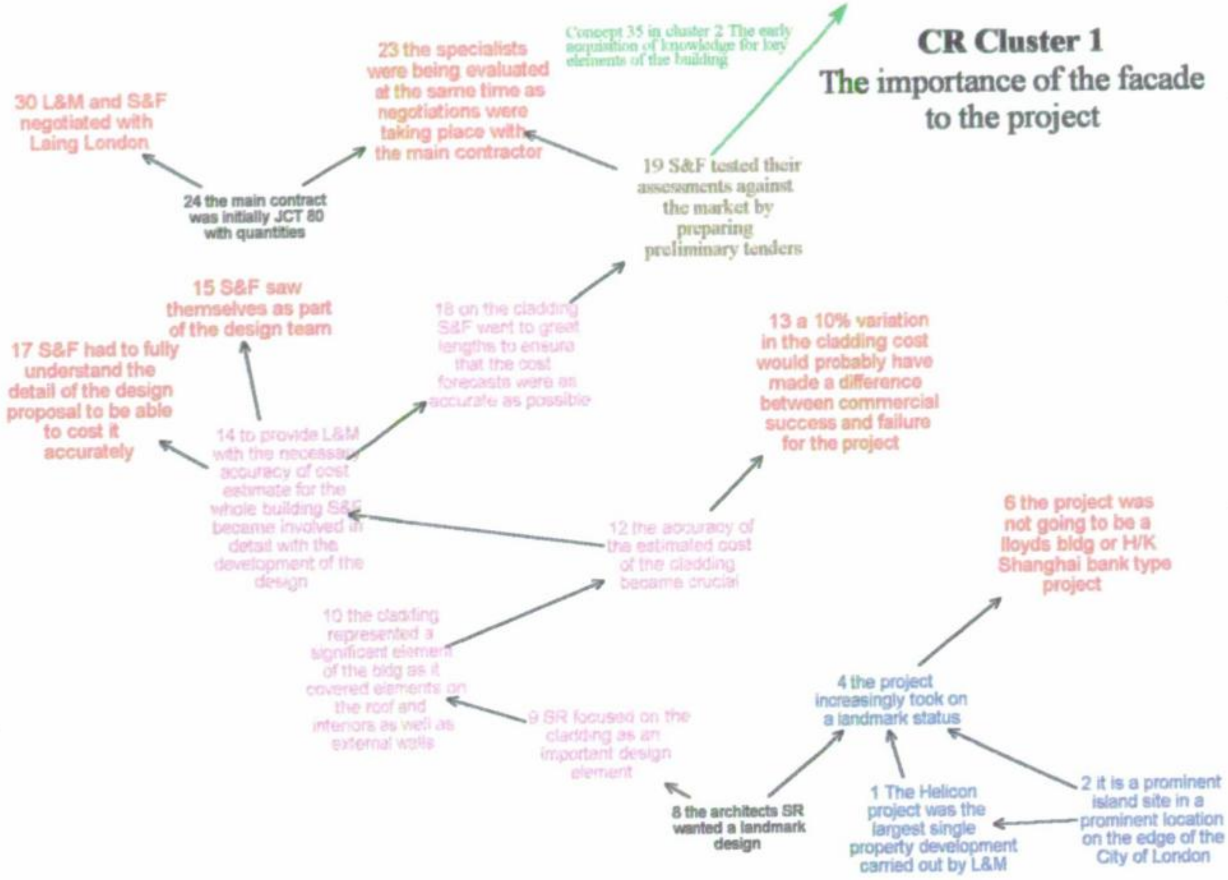


JP Cluster 8
The client's appreciation of the reasonableness in contract issues

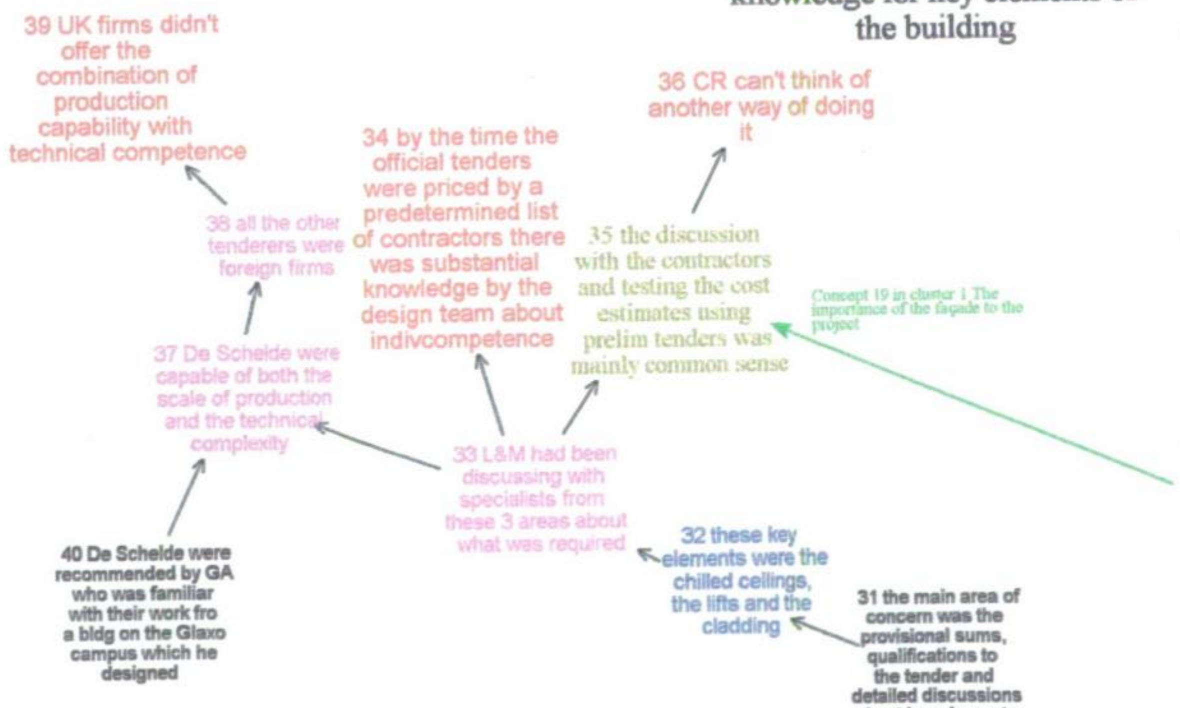

JP Cluster 9
The main contractor 's involvement in the design
172 there has been good 3 way relationship
173 in comparison with other recent projects, Laing's performance has been very good
169 Laing did send representatives to the meetings between Scheldebauw and SR
171 Laing do not stop direct discussions between the consultants and the trade contractor
166 the appointment of the cladding contractor was negotiated, based on returned tenders
168 Laing do not usually get involved in design issues
175 the division of OAP which JP works for is currently doing mainly o/seas work which is fortunate
165 the contract with Laing was negotiated upwards
170 Laing do have an M&E coordinator
167 under a JCT 80 the design is largely complete
174 the problems associated with very low tender prices are the biggest problems faced in the construction industry at the moment
163 DL's view was that if appointments were made then he would spend the next 2/3 yrs arguing the toss and not getting the bldg finished
164 for the appointment of the main contractor Laing were the lowest bidder
176 UK tender prices are still far lower than they should be, which means that there will be problems to be dealt with for the next few yrs
162 the tenders were returned with silly figures
Concept 161 in cluster 8 The client's appreciation of the reasonableness in contract issues


JP Cluster 10
The implications for such a complex facade
201 its effectivenesswould be heavily dependent upon the exterior control systems
202 the 3rd and 4th floors are potential dealing floors and the design has allowed for additional a/c systems (on floor fan coil)to supplement the main system
199 the performance of the a/c system will be largely dependent upon the use of the bldg
198 JP considers it a missed opportunity toset up automatic of the data through the BMS
Concept 101 in cluster 5 The complexity of cotrolling the facade
196 this is subjective and requires manual adjustment
52 the type of facade that the project has ended up with is a direct result of wanting a glass fronted building which has a highly effective a/c system
51 it would have been easier to have less things that moved or needed controlling, but this would not have met all the criteria set by the client
195 OAP know what the a/c system has been designed to handle but how does this equate with a series of sensors measuring external factors on the roof
194 the answer is to experiment and seek the views of those concerned, an iterative process
53 in order to meet the two requirements has required an increase in technology on the facade
49 this will put an additional requirement on the ongoing maintenance of the building
50 it is unlikely that there could be a more active facade
134 the problem was developing the design without spending more of the client's money
187 the last design issue left is making the the whole thing work
18 the facade is reasonably complicated in mechanical terms
48 JP has a nervousness about the viability of the designed scheme and making all the elements work
30 this provides a highly efficient triple glazed barrier in winter and a naturally ventilated thermal shield in summer
133 from SR's point of view JP is aware of the problems SR had with dealing with the design development with Scheldebauw
132 JP's view is that there are concerns over how complex the facade has got
28 the control of the vents is by a thermostat mounted inside the void which activates the motors on the vents when preset temps are reached
Concept 123 in cluster 6 The control of the facade's mechanical elements
19 OAP have to make the vents open and close when required
24 the facade is active in many ways
Concept 16 in cluster 1 OAP's involvement on the Helicon project
Concept 20 in cluster 6 The control of the facade's mechanical elements

CR Cluster 1
The importance of the facade to the project

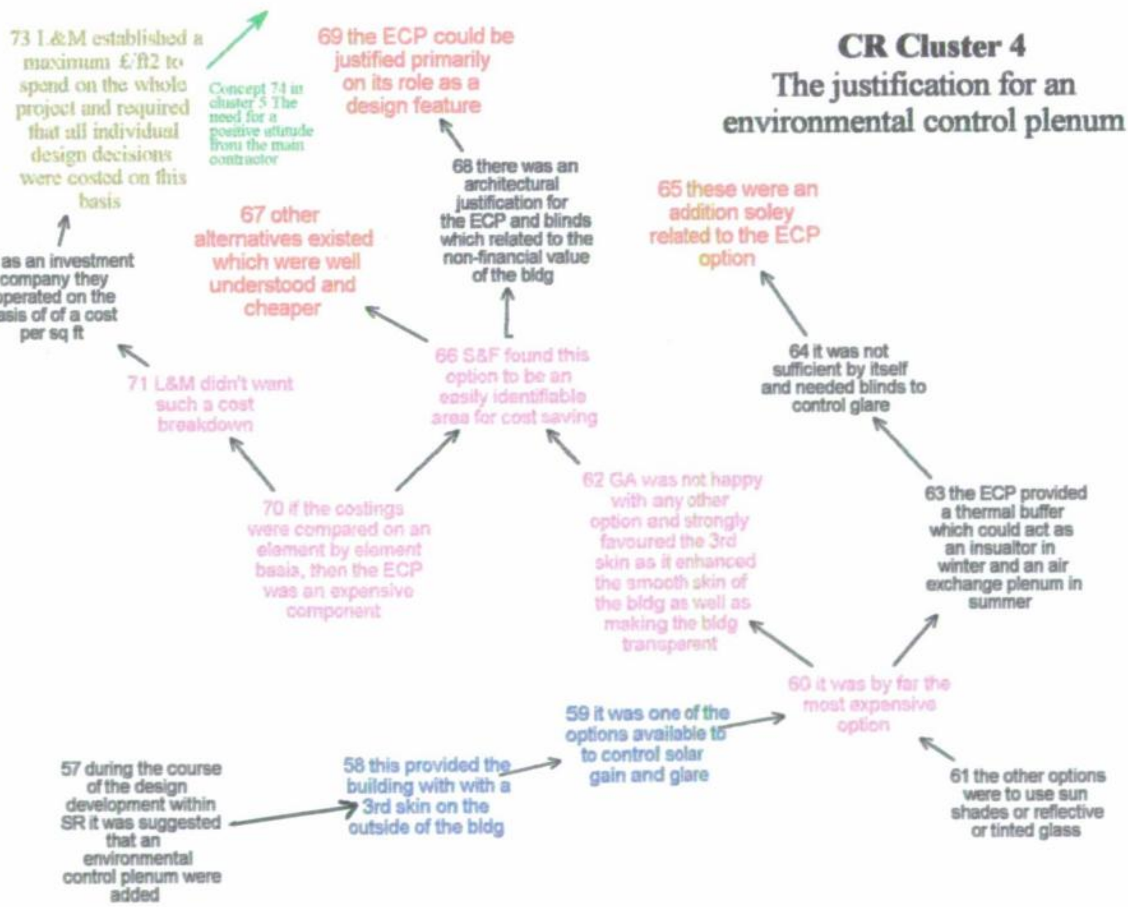


CR Cluster 2
The early acquisition of knowledge for key elements of the building



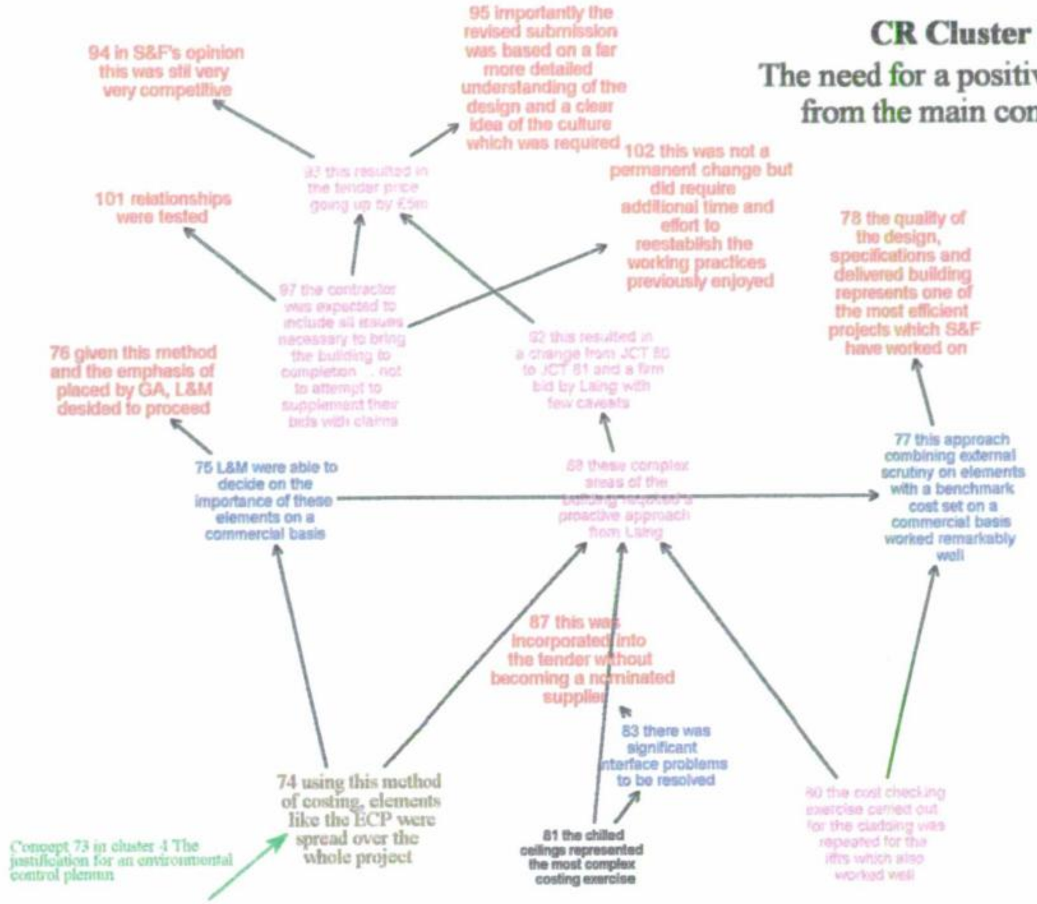
CR Cluster 3
The careful selection of the best trade contractor

CR Cluster 4
The justification for an environmental control plenum



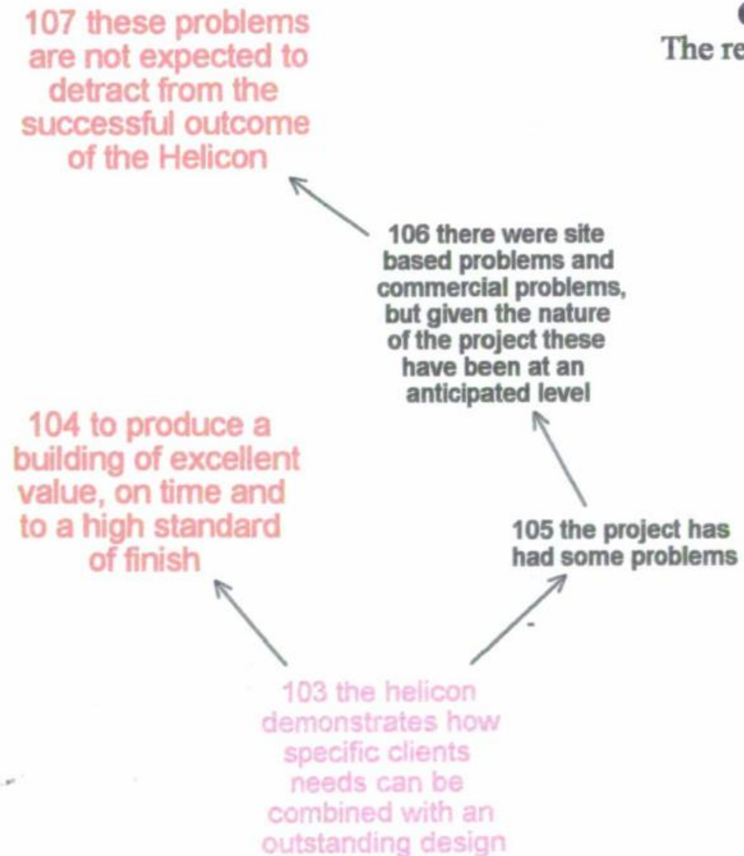
CR Cluster 5

The need for a positive attitude from the main contractor



CR Cluster 6

The results of the Helicon project



CR Cluster 7

The need for the right set of individuals

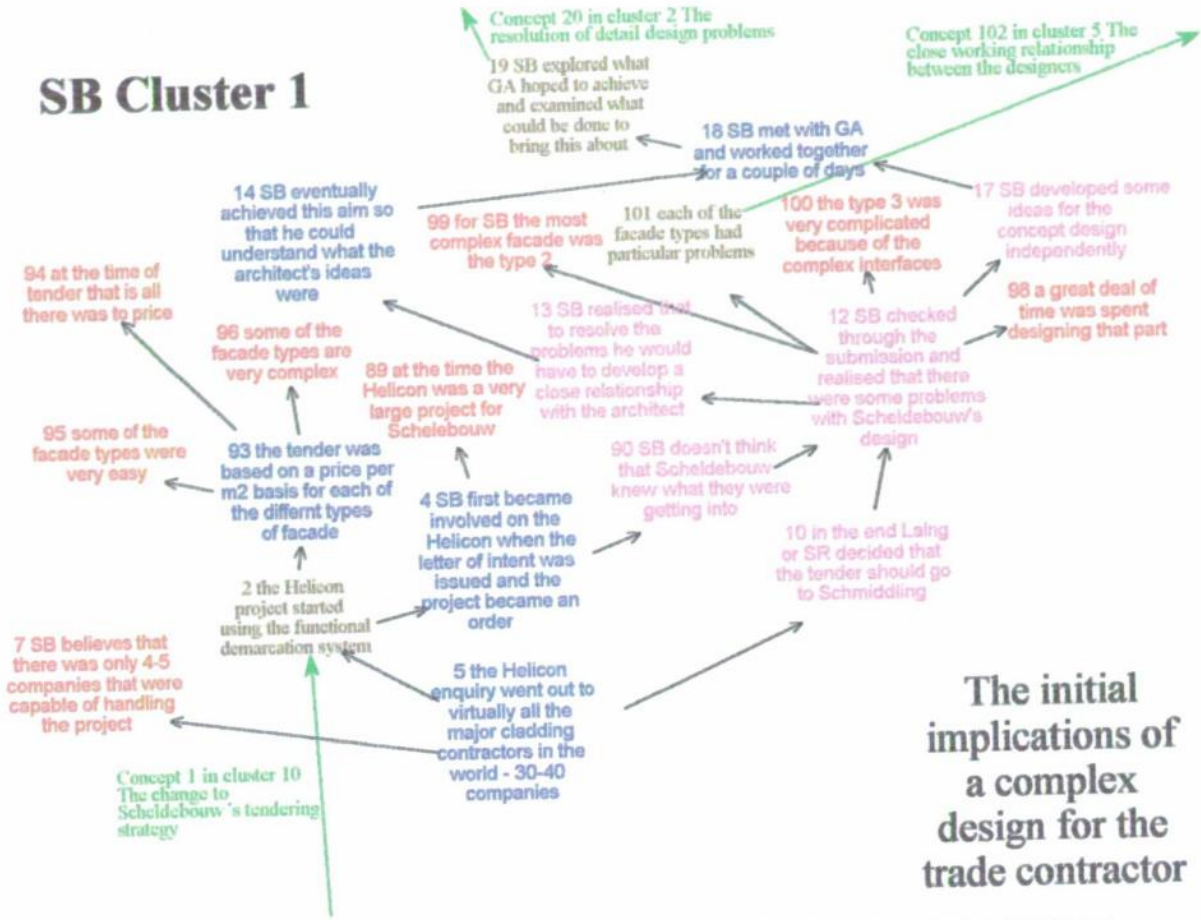
108 S&F were keen to create a culture of reasonableness on the project

109 the important factor is the is the relience of negotiation which itself requires the right type of individual

110 the main players on the Helicon were al able to adjust to the working culture

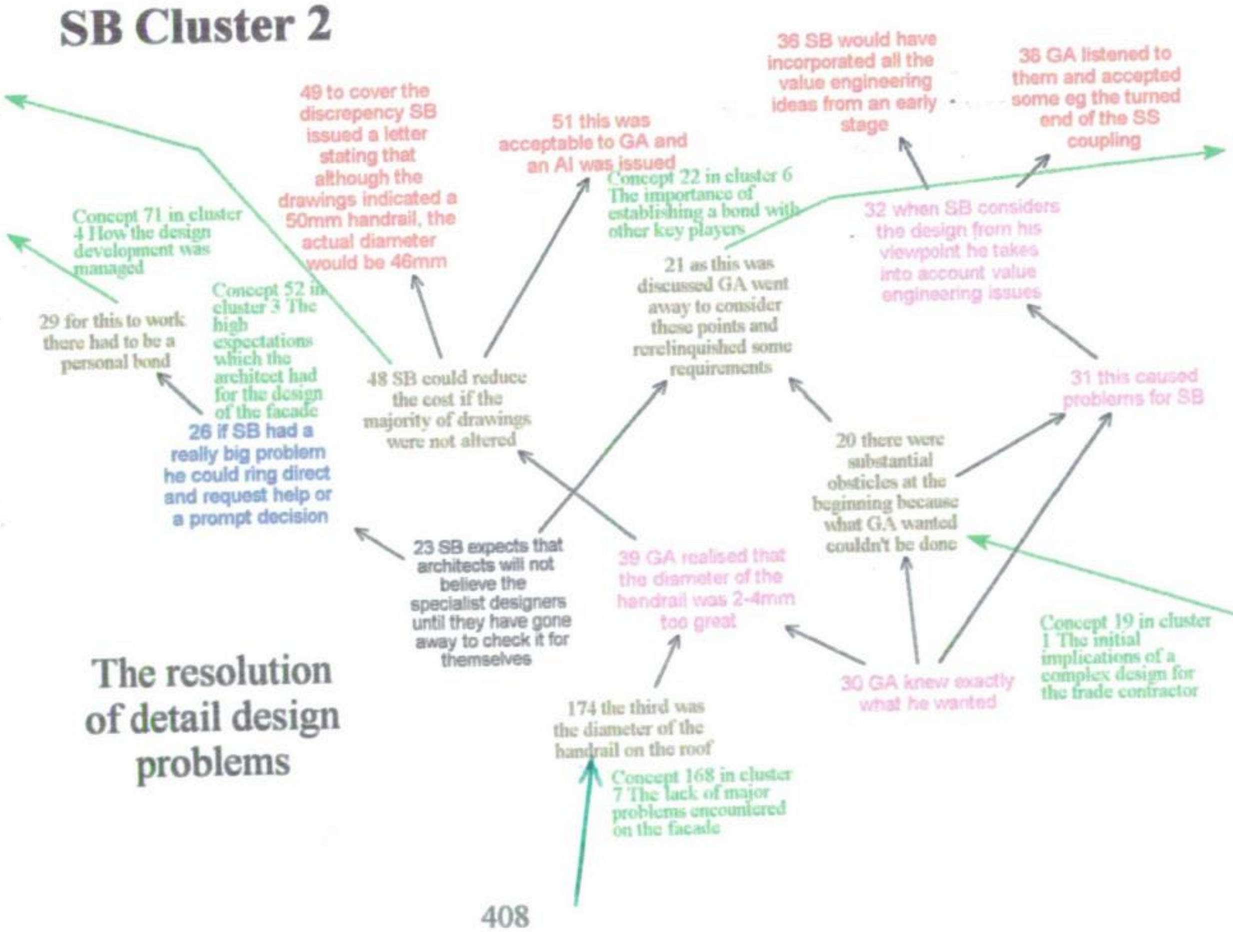
111 this has been reflected by allowing for the contractor's needs to include making a profit, as well as satisfying the client's requirements, both comm & n/c

SB Cluster 1



The initial implications of a complex design for the trade contractor

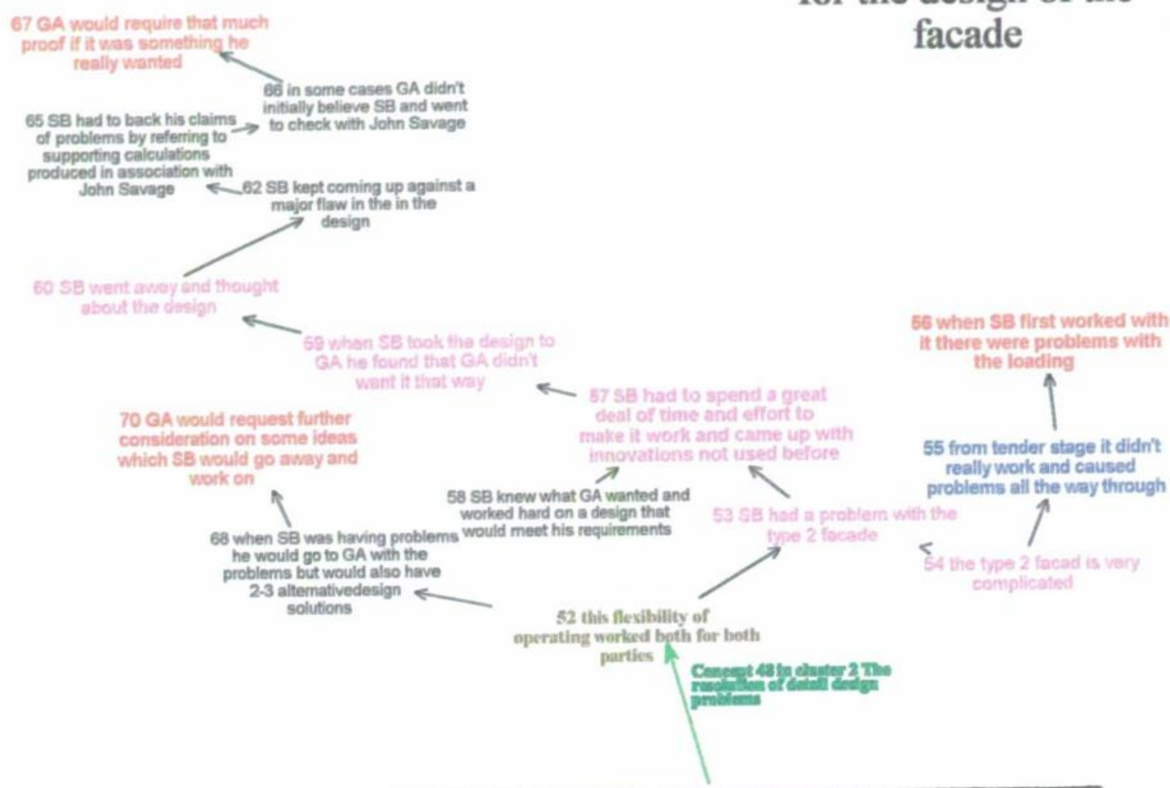
SB Cluster 2



The resolution of detail design problems

SB Cluster 3

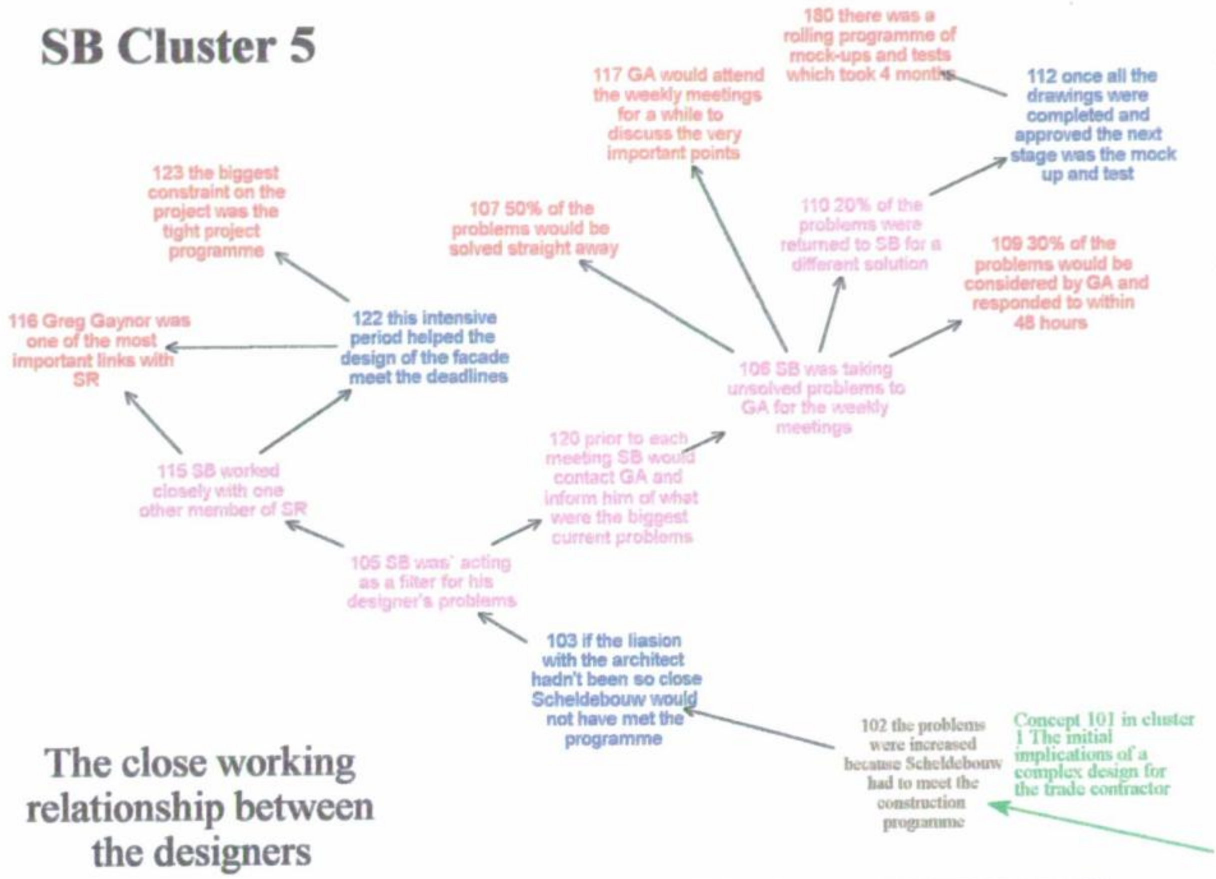
The high expectations which the architect had for the design of the facade



SB Cluster 4

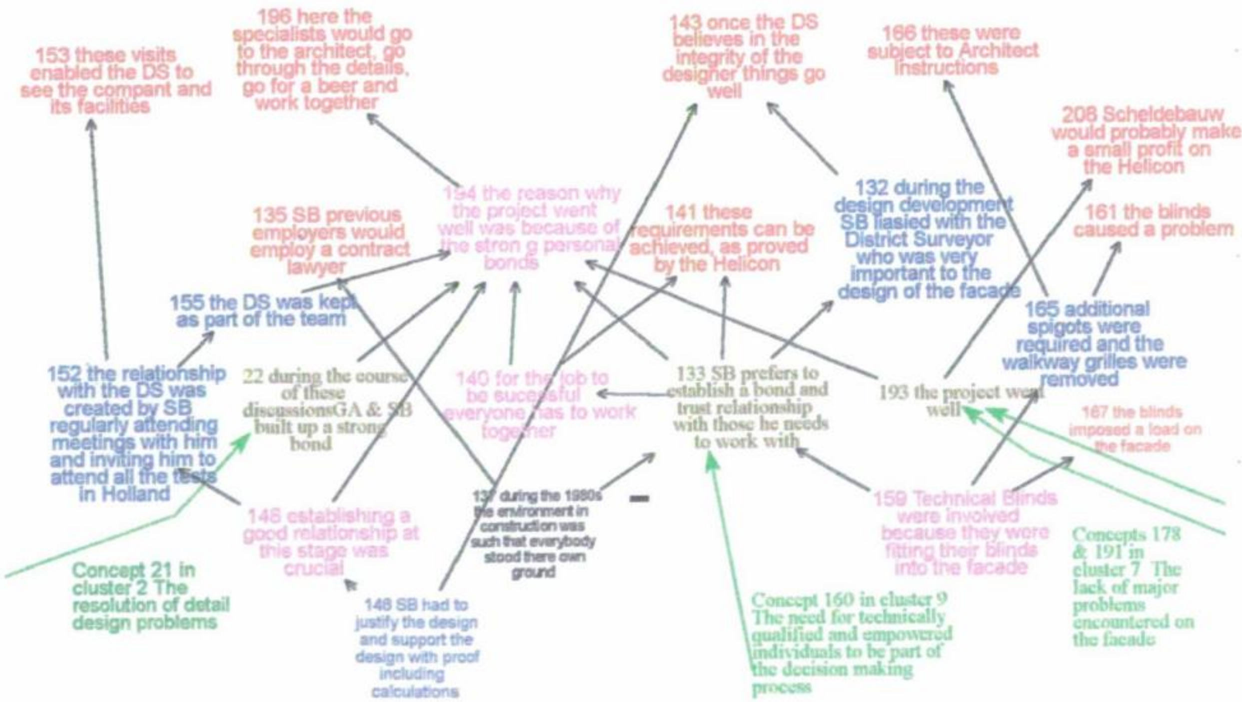
How the design development was managed

SB Cluster 5



The close working relationship between the designers

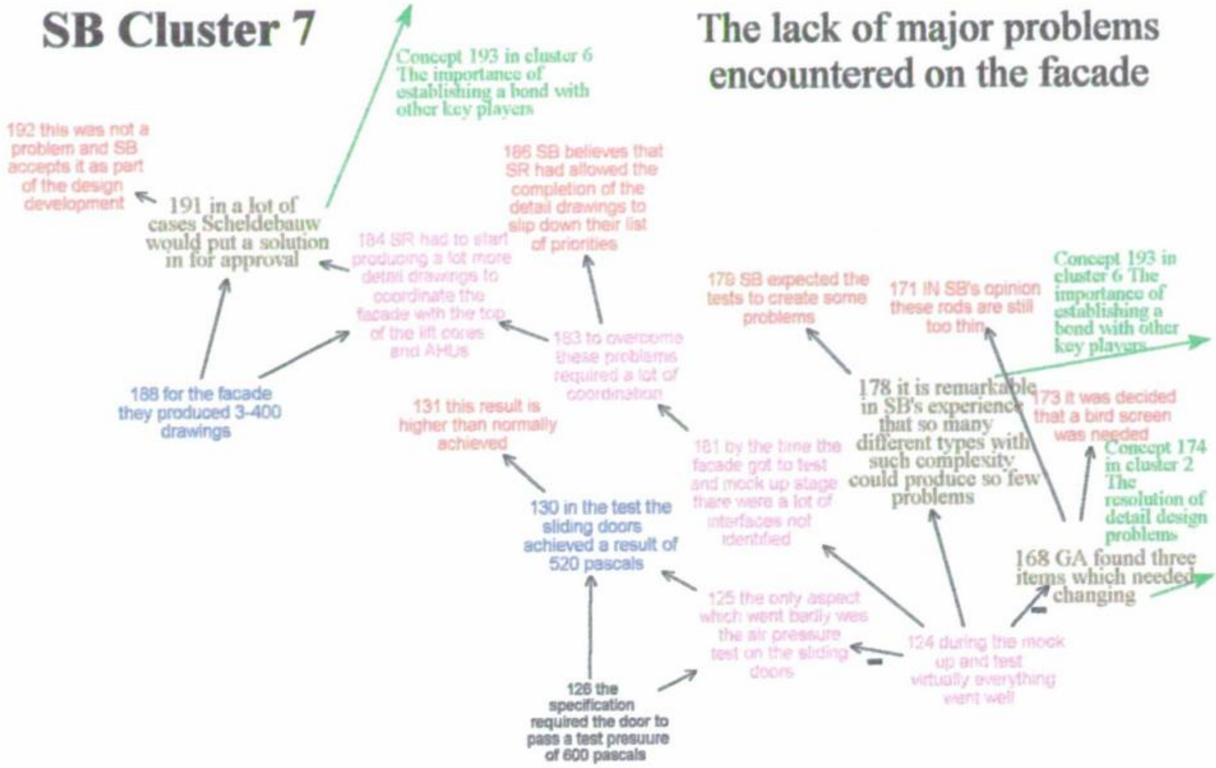
SB Cluster 6



The importance of establishing a bond with other key players

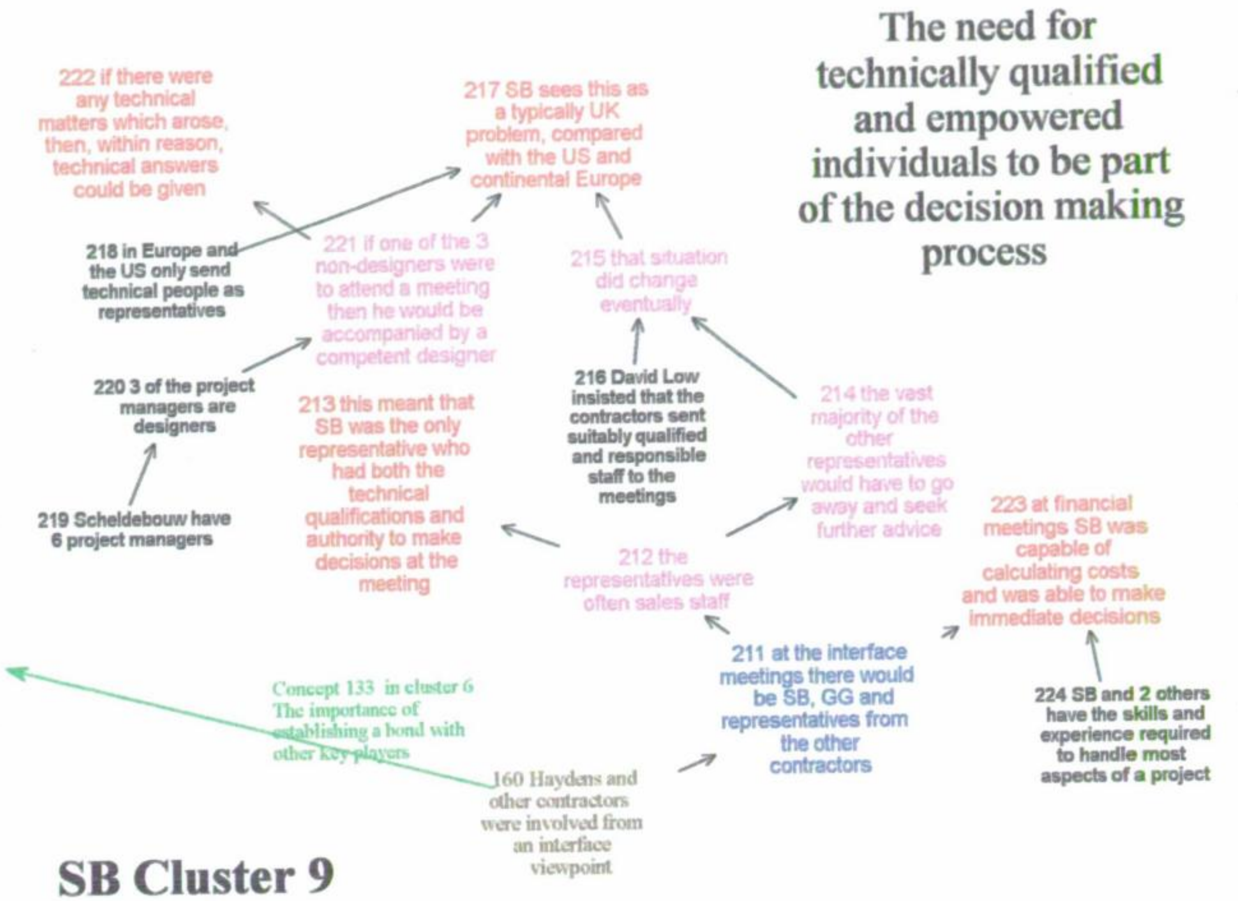
SB Cluster 7

The lack of major problems encountered on the facade



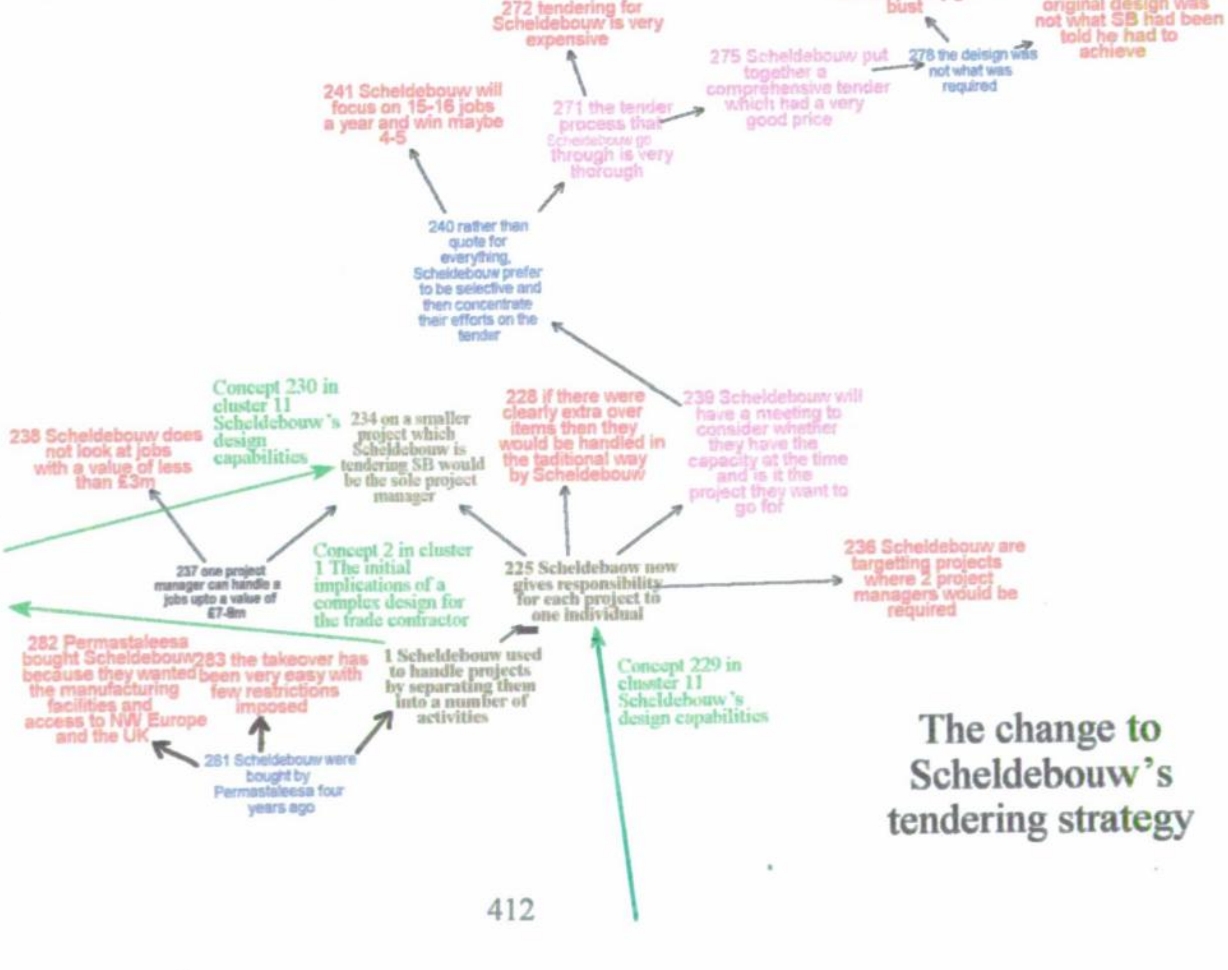
SB Cluster 8

The need to establish a direct relationship between the trade contractor designer and the architect



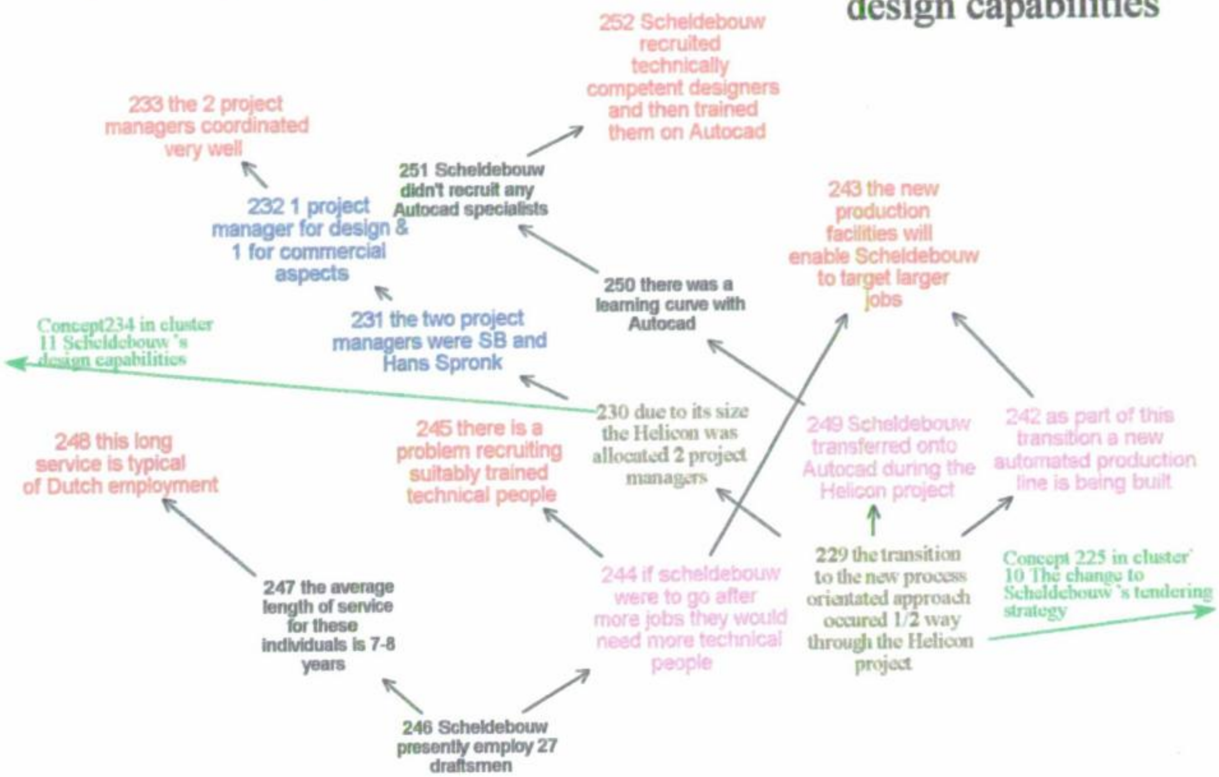
SB Cluster 9

SB Cluster 10

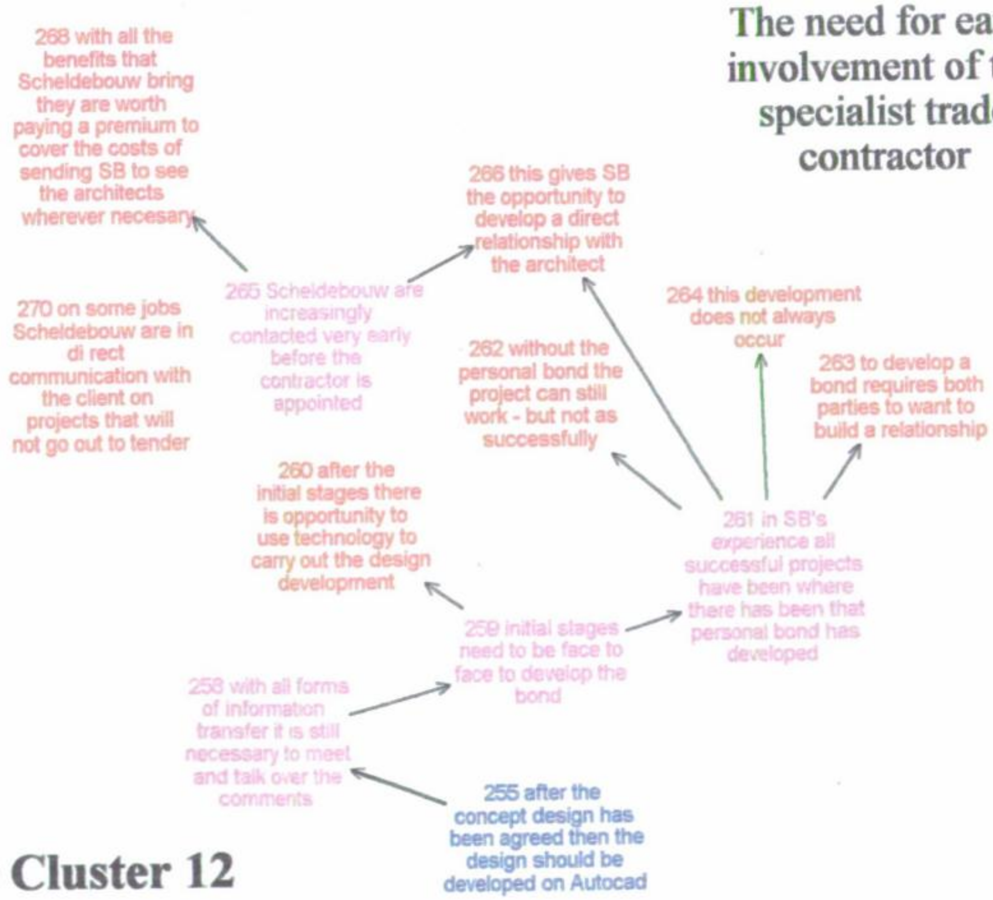


SB Cluster 11

Scheldebouw's design capabilities



The need for early involvement of the specialist trade contractor



SB Cluster 12

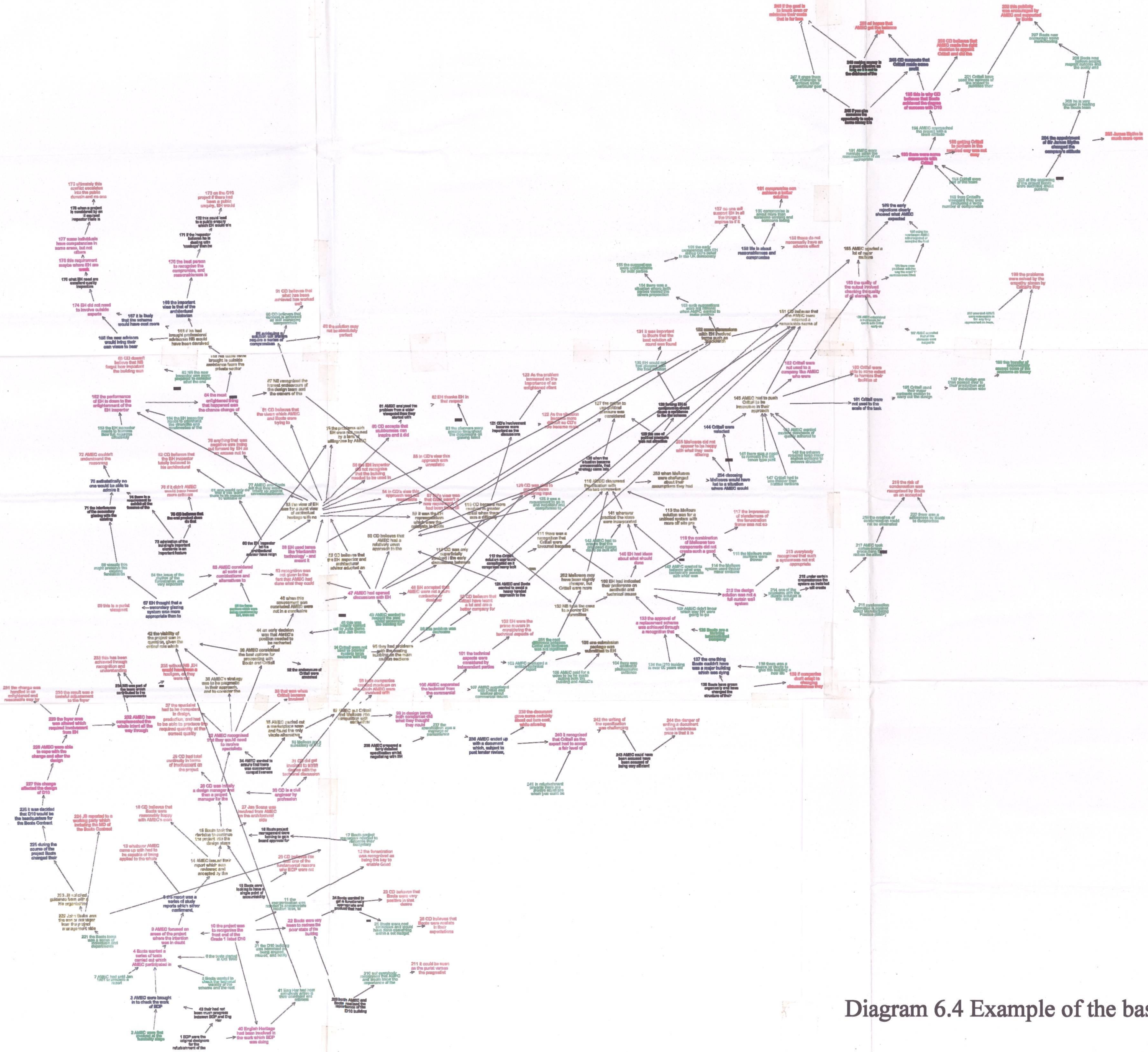


Diagram 6.4 Example of the basic cognitive map